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A Secure and Efficient Image encryption and compression approach for pseudo color image in cloud storage

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ABSTRACT

Cryptography and compression techniques are being used to secure and safeguard images in response to the growing requirement for data and information transmission in a safe and secure manner. Cloud as a blooming technology offers numerous applications and services in today's market to user's on-demand in an inexpensive way. One can say that it is rightly hyped. The demand to store a large number of images on social media, E-Health and other domains has increased drastically over the years. Because of this increasing usage of digital images,an encryption technique followed with a compression technique that is faster and efficient is needed for cloud applications. The digital images are stored in the cloud server that can be accessed by the user when required..This paper proposes a structured and comprehensive work of image cryptography and compression using hybrid encryption and Deep Learning in order to encrypt the image and also to reduce the storage capacity of the data with images. The method of compressing and rebuilding the image later on, if necessary, can offer storage efficiency.

Keywords

Image encryption,Image compression, CNN, Autoencoder

1. INTRODUCTION

In Cloud computing provides various resources and services on demand over the network for instance platform, software and infrastructure. It facilitates huge storage capacity and builds a virtual infrastructure for its users using remote computing. Few examples of cloud computing service providers are Google, Amazon, IBM, etc. These service providers also offer data storage like Simple Storage Service (S3) construct on Google Drive and the Amazon EC2 along with online access to other resources. It also increases storage efficiency by raising the data availability and faster processing of data over the cloud. It rents virtual machines and storage space to store information, organizational data and application data. It achieves storage from optical storage media, flash memory, magnetic tapes and disks attached to network storage in storage space management. In today's world, the most effective way of representing information i.e., digital images have scattered the network and taken up much of the storage space. Using communication lines where images are sent is prone to being intercepted or stolen by eavesdroppers, which makes data safety of the utmost concern. The process of hybrid encryption leads to the image security for the user to store images on cloud storage. This techniques is followed with image compression to compress the data for transmission applications and data storage in a favorable way that reduces transmission time and bandwidth. Image Compression comprises two methods: Lossless compression and Lossy compression. Lossless compression is adequate for the reason that there is no loss of data over cloud storage in this technique. Whereas in Lossy compression, a little loss of information occurs but it goes unnoticed in the human eye.

A) IMAGE ENCRYPTION

Encryption is necessary if photos are to be sent securely and remain secret. The pixel intensity of the input image must be twisted to create a cypher image in order to carry out the encryption operation. that is very different from the supplied image. Using the secret keys, the recipient decrypts the message, produces the original image, and gives it to you. A separate private key is used by the sender and the recipient. They are also used to generate the shared secret key in asymmetric key cryptography. Regarding the Conversely, symmetric-key cryptography encrypts and decrypts data using the same key. Only they are aware of the sender's and recipient's identities.

B) IMAGE COMPRESSION

Going a step deeper into data security, we consider image security. It becomes extremely necessary to protect private and copyrighted images since images form a major part of online data in the cloud. There has been a noticeable shift in the trend of saving personal images and videos on the cloud as a backup. This gives birth to various data security issues on the cloud pointing out to the fact that digital images are not completely protected in the cloud. There is a possibility of a massive breach on the cloud which might result in personal data getting leaked. This is why an efficient algorithm is a must for image security. To save storage space, the digital photos must first be compressed before being stored on the cloud. A depiction of a picture in the fewest possible bits is called compression. (Chowdhury and Khatun 2012). The following compression ratio is used to quantify the compression achieved by the following formula:

$$CR=n1/n2$$

Wheren1 denotes the number of bits in the original image

n2 denotes the number of bits in the compressed image.

In most cases, only those bits that carry important information are considered. The first step in image security is image compression but the selection of the image compression technique should be such that it is compatible with the cloud computing system. Table 1 presents the description of the image compression methods (Katharotiya et al. 2011)

Table 1 Methods of image compression

METHOD OF COMPRESSION	DESCRIPTION
1) DWT (discrete wavelet transform)	1) Has a higher ratio of compression. 2) Determines which information is more crucial to how people perceive things. 3) Employs a better combination of functions for the acute edges.
2) DCT (discrete cosine transform)	1) Has a quicker performance time. 2) Makes best use of the coefficient. 3) Does not produce an appearance like to a block.

Comparison of discrete wavelet transform and discrete cosine transform: Image compression and decompression methods (Gupta and Choubey 2015)

2. II. RELATED WORK

Al-Maadeed et al[39] combined approach of selective image encryption and compression was put forth. The main goal of this suggested technique is to show how using multiple keys can increase security by upping the number of external keys used in each encryption operation. An encryption technique based on chaos that approximates the outcomes of the DWT transformation is used during the encryption process.

In their combination of lossless compression using the Quadtree and Huffman coding method and symmetric cryptosystem using the partial method, Hassan and Younis[41] proposed a way to incorporate encrypted data into compressed data using the AES method. A hybrid picture encryption-compression technique based on CS and random pixel exchange was proposed by Zhou et al.[45], where compression and encryption are carried out simultaneously. The first compresses and encrypts the image by splitting it into four blocks. After that, the randomised pixels are exchanged and compressed and encrypted. A CS-based encryption approach that effectively combines sampling, compression, and encryption was also proposed by Huang et al. [46]. The testing results show that the suggested encryption method does not produce exceptional unpredictability; even the diffusion and sensitivity method, when used concurrently, performs better than image encryption.

Autoencoders were initially considered as the default image compression neural network because of their ability to reduce dimensions, extract complex visual representations, and convert images to compressed binary formats [15]and other applications. Nowadays, various auto encoders used to capture hidden representations directly have been gaining so much popularity due to their parameterization trick and generative nature[12].

Over the years, the image compression study using Deep Learning has gone beyond autoencoders. Toderici et al[1] proposed variable-rate image compression that presents a recurrent neural architecture based on convolutional LSTMS (Conv. LSTM). Earlier, neural networks required a fixed compression rate. But this framework compresses 32*32 sized images that help obtain better SSIM values than JPEG. However, it was limited to 32*32 sized images. The researcher presented [2] another method where images of varied size could be used; provided they were multiples of 32*32. The results of the second research were superior to JPEG results.

Johnson et al [4] further researched by incorporating hidden-state priming, spatially adaptive bit rates and SSIM weighted loss and obtained improved results. [3] It trains autoencoders for image compression, out-performing the RNN based approaches and make auto encoders efficient with the help of sub-pixel architecture. It implements a recurrent autoencoder for image compression that supports spatially adaptive bit rates and a loss function built on structural similarity (SSIM). It presents non-line art transform coding for image compression, optimized end-to-end for rate-distortion performance. [6] It implements GAN's for image compression that helps in obtaining significantly lower bit rates than the previous state of the art.

Figure 1 –

1. DATA:

Four pseudo color images are selected i.e.Lena ,Cameraman,Babbon and Pepper. All the images are of varying sizes having varied content. The CNN encoder required fixed-size inputs for the fully connected layer.

2. METHODS, EXPERIMENTS AND RESULTS

Hybrid encryption and compression technique

The Elliptic Curve Cryptography (ECC) with Hill Cipher (HC) image encryption and decoding methods are combined.

Km = K- 1 is a self-invertible matrix that is created for Hill Cipher. The self-invertible matrix is a 2 by 2 size. By using the most original picture pixels to create the corresponding cypher pixels, a self-invertible matrix of 4 x 4 size performs the encryption and decryption process relatively faster and causes more distortion in the encrypted image. It is not necessary to send the matrix along with the encrypted image because it may be derived from the shared secret key. This technique focus on the encryption and decryption process of pseudo color image.

Evaluation Metric

We have evaluated our results in terms of PSNR (Peak Signal to Noise Ratio) and Structured Similarity (SSIM) in the field of image compression. PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise.[9] It is most easily defined in terms of mean squad error (MSE), which is the cumulative squared error between the compressed and the original image.

Given an image l (x, y) of size (M*N) and the compressed version l' (x, y), MSE and PSNR are defined in the equations below[10]: MSE = 1 MN Σ My = 1 Σ Nx = 1[l(x, y)-l 0 (x, y)] 2 PSNR = 20*log 10 255√MSE

A higher value for PSNR/a lower value for MSE means less error between the original and compressed image.

SSIM is another evaluation metric for gauging the similarity between two images. PSNR and MSE consider an estimate of the absolute error whereas SSIM considers the perceived change in structural information while incorporating perceptual phenomena such as luminance masking and contrast masking.[11]

To calculate SSIM between two images, we have used the SSIM function that takes values between 0.0 and 1.0. A higher value indicates a higher similarity between the two images. For autoencoders that produce a fixed-size encoding, the compression rate and the space are also considered evaluation metrics. There is a natural trade-off between reducing the size of an image and maintaining the quality of the image. The input image having a perfect SSIM and PSNR score will be the 'compressed' version. Practically, it is useless as it occupies the same amount of space. As we go on reducing the size of the image, the quality of the image also drops. Let us know about this aspect of image compression with the following:

$$\text{Compression ratio} = \frac{\text{size of uncompressed image}}{\text{Size of the original image}}$$

3. CNN AUTOENCODER

An autoencoder is a deep neural network model that can receive input data, compress and grasp its structure by propagating it through multiple layers, and then create the original data again. An autoencoder uses an encoder and a decoder, two distinct types of networks, to accomplish this operation. Layers within the encoder are reflected in the decoder.

Our initial study model is a simple convolutional autoencoder architecture. It is made up of an encoder that converts an input image into a code, which is a representation of the compressed image in intermediate form. It is made up of a decoder that processes the code and reconstructs the original input in a lossy manner.

For the baseline architecture, the encoder is a convolutional layer, followed by a non-linearity (ReLU), and later followed by a dense layer. This creates the compressed form of the image (the code). The decoder is a de-convolutional layer, followed by a non-linearity and this non-linearity act as a sigmoid for the output to have pixel values in the same range as the original output. The architecture is shown in Figure 2.

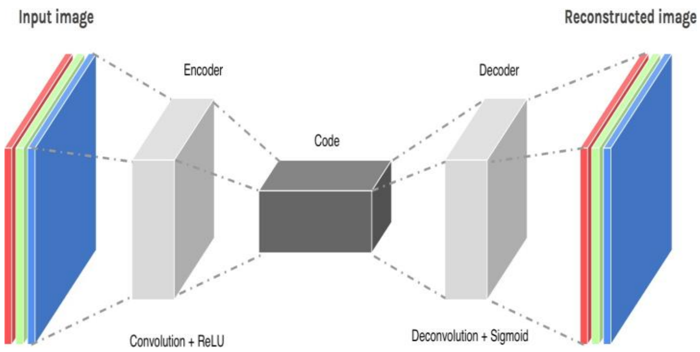

Figure 2 CNN autoencoder architecture

Table 2 Results of both the auto encoder models on test set

	Conv. AE	VAE
Average PSNR	**71.05**	**58.17**
Average SSIM	**0.93**	**0.21**
Compression Ratio	**0.01**	**0.13**

3. EXPERIMENTS

ENCRYPTION PROCESS:

(A) reads the picture that has to be encrypted and gathers the pixels for the channels r, g, and b independently.

(B) Use the calculated self-invertible matrix to conduct matrix multiplication for each channel of pixels by grouping them into 4 x 4 matrices.

(C) The following formula is used to do the encryption:

Ci is equal to km. Pi

where pi is the current input image block that needs to be encrypted and km is the self-invertible matrix;

(D) Give the cipher pixels the exact same location as the corresponding pixels in the input image. The size of the cipher picture is the same as the size of the input image.

(E) Forward the recipient the cipher image and the ecc public key. An illustration of the encryption process is shown in figures 3, 4, 5, and 6.

(F) Since the cnn autoencoder model has fully connected layers with images of varying sizes, all the images are resized to be of the same size (128*128).

(G) The convolutional layer has been chosen in the encoder for 32 filters, each of size 3*3 and stride 1. The output has been transformed from a convolutional layer into a code of dimensions 1*128 with the help of a fully connected layer

(H) There are 3 channels in the de-convolutional layers in the decoder that made the output match the original input (1*1 filters). This baseline model is based on the training set of 585 images using adam optimizer and mse as the loss function.

(I) The learning rate has been tuned from range 1e-1 to 1e-4 using the validation set provided (41 images). The model with the lowest loss on the validation set was evaluated on the test set.

4. RESULTS

The model with the highest PSNR and SSIM scores was trained with the learning rate 1e-3. Table 1 shows the results of our best models on the test set. The table represents a list of average PSNR and SSIM scores on the test set with the compression rate. Here,

$$\text{Compression ratio} = \frac{128 \times 4}{128 \times 128 \times 3}$$

This is because the compressed image (code) is of size 1*128 with floats and the original image is of size 128*128*3 with Unit8 characters.

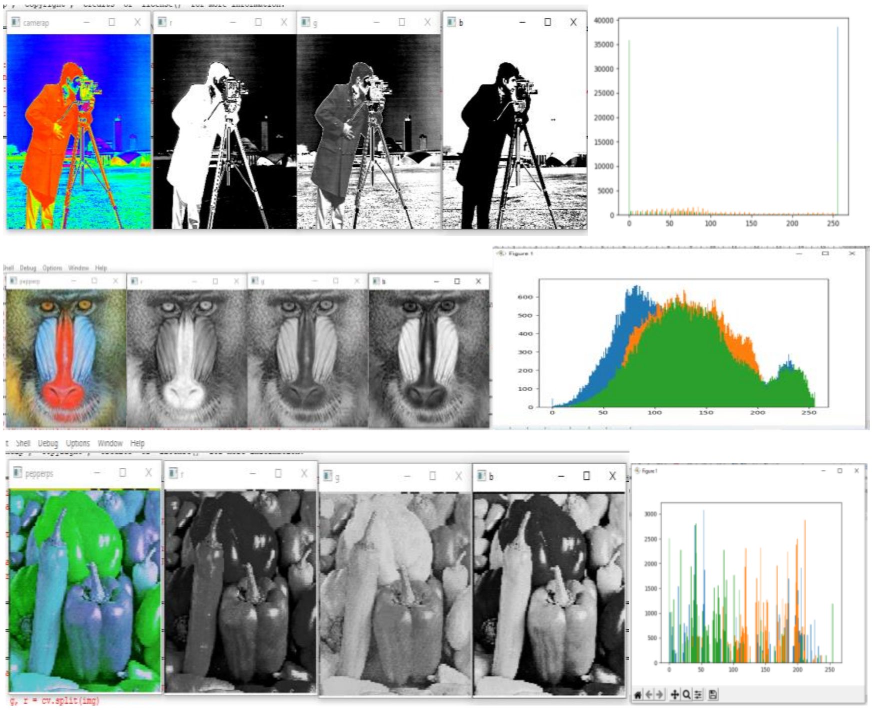

Figure 3-6 Left: Original images. Right: Compressed images

Figure 3,4,5,6 shows few illustrations of encrypted and compressed images from the model. The model performs well despite the significant encryption and compression of pseudo color image. The drawback of this model is that variable-rate encoding is not possible which means in order to change the compression rate; the autoencoder needs to be retrained.[1]

5. CONCLUSION

Because of its extremely low computational cost, hybrid compression-encryption technology can provide real data protection while simultaneously improving the efficiency and security of images being transferred. Therefore, by increasing the efficacy of each compression and cryptography approach separately, the concept qualifies for and may improve data security and transmission efficiency. It is anticipated that this concept will be able to combine the advantages of symmetric and asymmetric cryptography techniques with the best aspects of lossy and lossless compression techniques with the drawbacks of symmetric and asymmetric techniques, especially in relation to cypher key management, to produce data that is significantly smaller in size while maintaining high quality during reconstruction and security assurance.. The cost and skill level of photography have significantly decreased in the past due to the widespread use and quick development of handheld cameras. Every day, people all around the world take and share pictures with their digital cameras, cell phones, and other portable devices. People utilize it to share their experiences and daily lives, as well as to advertise their businesses. These days, it's imperative to safely store and manage these enormous volumes of images. Here, we offer our CNN-based autoencoder image compression technique, which reduces image size, increases drive storage capacity, and encrypts images using hybrid encryption in the cloud.

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