International Journal of Engineering & Technology, 7 (2.2) (2018) 62-64

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

Image encryption using vigenere cipher with bit circular shift

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Abstract

Cryptography is a method of securing text data, images and sound in order to secure its confidentiality and to minimize data stealing, attack, etc. The purpose of this study is to improve classic Vigenere cipher using bit circular shift on image encryption. This experiment uses both RGB and grayscale images as samples and shows that Vigenere cipher with bit circular shift has better performance when encrypting an image both visually and its randomness. It is obtained the MAE values of images of final encryption process are 81.702637 of RGB and 73.678756 of grayscale, and the final decryption process of 0 for both images. The randomness of images of the final encryption process is shown by its correlation coefficient values; it is 0.033857 of RGB and -0.058501 of grayscale.

Keywords: *Vigenere chipper; bit circular shift; image encryption.*

1. Introduction

Data and information are important commodities both for individual and organizational. Information can be presented in form of text, image, audio, video or mix of it. Some information is available and accessible to the public where some are secrets. In order to secure information, cryptography can be applied. Cryptography is the science of keeping secrets secret [1], [2]. It is the science of secret writing with the goal of hiding the meaning of a message[3].
While securing information, cryptography can be divided into two processes. It is encryption and decryption. Encryption is a process of hiding the information and decryption is the process of extracting the information from encrypted information. To implement encryption and decryption, it needs an appropriate encryption and decryption algorithm[4]. In this paper, Vigenere cipher will be used for image encryption and decryption. Vigenere cipher is a classic cryptography implemented symmetric keys. It is a polyalphabetic substitution that works based on Caesar cipher implementing Vigenere Square[5].
In this digital world, an image is a collection of the pixel which has different intensity values[6]. Each image consists of *n*m* number of pixel, where *n* is the number of rows and *m* is the number of columns. A pixel (**pic**ture **el**ement) is a small block that represents the amount of gray intensity to be displayed for that particular portion of the image. For most images, pixel values are integers that range from 0 (black) to 255 (white). For example, an enlarged image with 15 x 15 pixels shown in Figure 1 that shows its gray intensities and Figure 2 that show its corresponding intensity values.
An RGB image or a true color image is an image in which each pixel has three components value[7]. These components are red (R), green (G) and blue (B), so that the RGB image are *m-by-n-by*-3 array of class uint8, uint16, single, or double whose pixel values specify intensity values. The multiple values may correspond to different color intensities as shown in Figure 3.

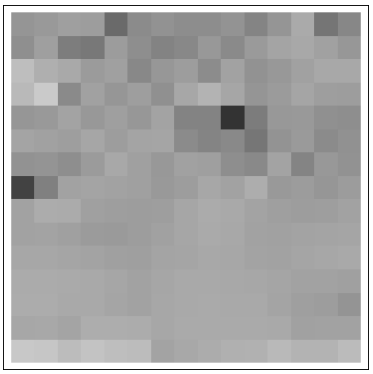


Fig. 1: The 15 x 15 pixel of an enlarged image

150	154	160	157	106	140	147	142	141	147	132	150	171	117	136
144	159	125	121	157	143	132	136	153	138	155	164	169	162	152
190	175	169	155	161	136	152	158	141	162	147	153	161	168	169
185	203	139	161	151	159	145	167	179	167	150	155	165	159	158
151	153	163	152	160	152	164	131	131	51	124	152	154	145	143
164	162	158	167	157	164	166	139	132	138	119	148	154	139	146
147	148	143	155	169	160	152	161	159	143	138	163	132	152	146
66	129	163	165	163	161	154	157	167	162	174	153	156	151	156
162	173	172	161	158	158	159	167	171	169	164	159	158	159	162
163	164	161	155	155	158	161	167	171	168	162	162	163	164	166
167	167	165	163	160	160	164	166	169	168	164	163	165	167	170
172	171	170	170	166	163	166	170	169	168	167	165	163	163	160
173	172	170	169	166	163	167	169	170	170	170	165	160	157	148
167	168	165	173	173	172	167	170	170	171	171	169	162	163	162
200	198	189	196	191	188	163	168	172	177	177	186	180	180	188

Fig. 2: The intensity values of 15x15 pixel of an enlarged image

According to its compression algorithm, the image can be classified into lossless type and lossy type. A lossless type stores an exact representation of the original image in a smaller number of bytes that can be expanded back to its uncompressed form using a corresponding decompression algorithm. Meanwhile, a lossy type stores an approximation representation of the original image and while it

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expanded back to its uncompressed form, it is slightly different but visually is the same. PNG and BMP are samples for lossless type while JPG is a sample of lossy type.

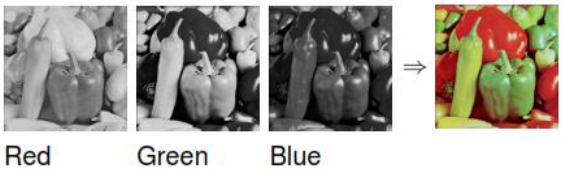


Fig. 3: Three components of an RGB image

Many studies have implemented in order to secure image. For example, implementing Rubik's Cube Principle that scrambling the original image then applied an XOR operator using two secret keys[8]. Sajid[6] divides the original image into some smaller images, encrypted and sent part by part. Meanwhile, Vigenere with Playfair cipher has been exploited for image encryption on a mobile phone[9], [11]. The aim of this paper is to show that the addition of bits circular shift on Vigenere cipher can produce a good result on image encryption.

2. Experimental details

In this study, an image that used as input can be lossless type or lossy type, but lossless type will be used to store the encryption output. As samples for encryption and decryption purpose is lena.jpg with 225x225 pixels in size, both RGB and grayscale. The original formula of Vigenere cipher for encryption and decryption is [10]

C = (P + K) mod 26 (1)
P = (C - K) mod 26 (2)

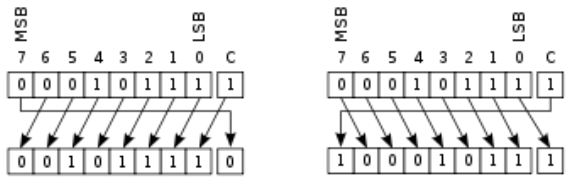
The value of 26 is the representation of the number of letter from A to Z, which is then represented by the numbers 0-25 which indicate the position of the letters in alphabetical order
Since the pixel intensity is a number value of 0-255, then the original Vigenere formula need to modify to accommodate these new value range. The modified formula for encryption purpose[9] is

C = (P + K) mod 256 (3)

and for decryption purpose[9] is

P = (C - K) mod 256 (4)

These encryption and decryption process is applied to all intensity values in each pixel.
Furthermore, bit circular shift is applied to improve the encryption result of Vigenere cipher. This step is needed since the encryption result of Vigenere cipher visually still showing the original image, although mathematically has shown a different data. The circular method that used for bit shifting process is rotated no carry as illustrated in Figure 4. In this operation, a bit is rotated as if the left and right ends of the register are joined. Any value on the right ends is taken and placed to the left ends of the register (Figure 4b), and vice versa.



(a). The left circular (b). The right circular

Fig. 4: Rotate No Carry

Implementation of Vigenere cipher and bit circular shift for encryption and decryption purpose is shown in Figure 5.

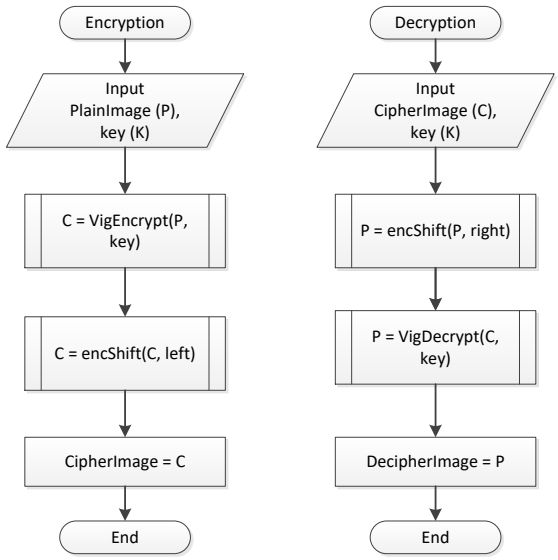


Fig. 5: Flowchart for encryption and decryption

Mean Absolute Error (MAE) and correlation coefficient were used to measure the performance of Vigenere cipher and Vigenere cipher with bit circular shift on images. MAE is used to assess how accurate the result of the decryption is compared with its original image, while correlation coefficient is used to assess how the randomness of cipher image compares to its original.
The correlation coefficient is calculated using the equation

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad (5)$$

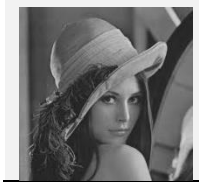
Mean Absolute Error is calculated using the formula

$$MAE = \frac{1}{n}\sum_{i=0}^{n}|x_i - y_i| \quad (6)$$

3. Results and discussion

In this study, the program for the encryption-decryption process is created using Python programming implementing OpenCV and numPy. Encryption conducted on intensity values on each color component in RGB image or grayscale intensity values in the grayscale image. The encryption result using Vigenere cipher is shown in Table 1 while it using Vigenere cipher with bit circular shift in Table 2. As the key to encrypt and decrypt is 'a1b2c3d4e5'.

Table 1. Encryption Result Using Vigenere Cipher

Plain image	Cipher image	MAE	Corr. Coef
		82.233468	0.127643
		73.028997	0.478397

It can be seen from Table 1 that pixel intensity change on RGB image is bigger than that grayscale image, which is indicated by a larger MAE value. Similarly, the randomness of the encryption results of RGB image is much better than the grayscale image,

indicated by the coefficient of correlation value that is smaller, i.e. 0.127643. Both encryption results are visually still easy to refer to its originals.

Differ from Vigenere cipher, encryption using Vigenere cipher with bit circular shift gives better results, both visually and data randomness. Visually the encrypted results have not shown the characteristics of the original image. The better randomness is showed by correlation coefficient value of 0.033857 compared to 0.127643 for RGB images and -0.058501 compared to 0.478397 for grayscales.

Table 2. Encryption Result Using Vigenere Cipher with Bit Circular Shift

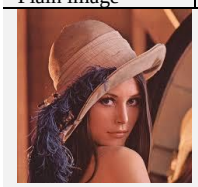
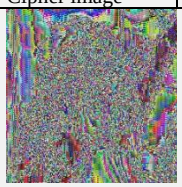
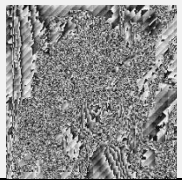
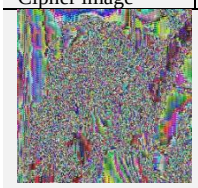
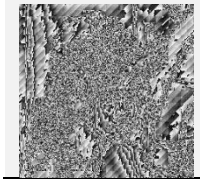
Plain image	Cipher image	MAE	Corr. Coef
		81.702637	0.033857
		73.678756	-0.058501

Table 3. Decryption Result Using Vigenere Cipher with Bit Circular Shift

Cipher image	Decrypted image	MAE	Corr. Coef
		0	1.0
		0	1.0

The decryption result is shown in Table 3. It shows that the MAE value is 0 and correlation coefficient value is 1.0 for both images, indicating that the decrypted images are perfectly matched to its originals.

4. Conclusion

In conclusion, this study has presented the performance of classic Vigenere cipher with or without bit circular shift. The MAE and correlation coefficient are computed on each result and compared to its original. Based on the result obtained image encryption using Vigenere cipher with bit circular shift give a better result than that Vigenere cipher only. A vigenere cipher with bit circular shift produces better randomness image that yields images that are difficult to recognize. Optimizing the circular shift such as pixel-level circular shift is one of the future works that can be conducted in order to investigate a better implementation of encryption-decryption in Vigenere cipher on the image.

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