Multilevel Blocks and Pixels Colour Values Scrambling Based Shifting Image Technique

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Abstract: With the rapid increase in the use of digital images, it is important to protect confidential image data from illegal access. Image scrambling is a useful approach to protect image data by confusing the image which can thus prevent it from being misused. The issues concerning the relationship among the adjacent pixels of the scrambled image, the weakness of visual leakage and produce a similar histogram plot, all affect the image scrambling process. This paper is aimed at determining the iteration level that is extracted from the secure key and the key mask for building a scrambling table which is used in the scrambling processes and the pixel colour values. The technique begins by dividing the original image that has to be scrambled into blocks whereby each block contains a specific number of pixels. These blocks are then scrambled by shifting the block positions in the image by using the vertical and horizontal scrambling method and then the pixel colour values are modified based on a scrambling table. The experimental results of the paper show that the block scrambling technique has reduced the relationship among the image elements. This is happened because of the entropy value of the scrambled images has increased and the correlation value is lower. Moreover, the scrambling degree of the scrambling technique has larger values for the scrambled image. Subsequently, the pixel colour value in the technique helps to confuse and amend the pixel colour values of the scrambled image to produce a different histogram plot when compare with the original images. The study also proves that a smaller block size yields higher entropy, low correlation, a high scrambling degree and have the ability to restore the scrambled images to their original form.

Key words: Block Image, Scramble Image, Image Entropy, Block Image Scramble, Image Correlation, Pixel scramble

INTRODUCTION

The world is facing daily rapid changes in technology due to swift advancements in computing, networks and communications. These advancements have opened networks and individual machines to a wide range of abuses by offenders. Offenders abuse the technologies in many criminal activities. In other words, they use technologies in various Cybercrimes [1]. A study found that there are relatively few criminal and civil cases which do not apply digital facilitation. It has been estimated that over 85 percent of criminal and civil prosecution cases are committed through the use of digital technology [2].

The impact of the Internet has contributed to the demand of digital media such as audio, image and video. It has not so much affected the creation of these media, but much on the reproduction and distribution, while in open networks most of the information is kept electronically. Therefore, the demand for protecting such images has gained more important [3].

The objective of image scrambling is to generate a non-intelligible image which prevents the human visual system or a computer vision system from understanding the true content. An authorised user is empowered to descramble the image using information regarding the scrambling method and the variables used in that process.
in order to decipher the image. Image scrambling has been proposed as a way to mitigate such issues since way back in 1960 when the first documented system to do so emerged [4]. The approach at that time involved scrambling, concealing or encoding information and unscrambling and decoding the received images used line screens and grids consisting of opaque and transparent lines. Over the years, image scrambling has evolved into two streams. One is based on matrix transformation to shift coordinates and the other makes use of permutations of the pixel coordinates.

Most of the scrambling approaches are based on an Arnold Transform or a combination of the Arnold Transform with other techniques [5-8]. These methods are applicable only to equilateral images. If the images are not equilateral, meaning the width and height are the same, then they have to be padded with values to make them equilateral [9]. Since most of these techniques do not use a 'key' that provides additional protection, Zhou et al. [10] proposed a Fibonacci P-code based scrambling algorithm which requires two parameters to be known by the receiver side to descramble the images. Even though this is certainly a favourable development over the other methods, just two numbers does not provide adequate protection. Wang et al. [11] proposed an approach of optical image scrambling with a binary Fourier transform and pixel-scrambling. For this kind of encryption algorithm, the orders of the pixel scrambling and the encrypted image need to be used as the keys to decrypt the original image.

Others [12-15] have attempted scrambling using random sequences based on chaos or pseudo random number generation based on parameters. Zhou et al. [16] proposed an algorithm using an M-sequence to shuffle image coordinates using two parameter keys. The M-sequence is a maximum length sequence that has been used in spread spectrum communications. It is a pseudo random noise sequence. In this approach, the authorised user is given the shift parameter r and the distance parameter p which are used to generate a 2-D M-sequence to descramble the scrambled image. Ye [12] proposed a scrambling method based on the chaotic cellular automata, which is used to scramble the digital image as a pre-treatment for the watermarking process. El-Latif et al. [17] presented a method for a scrambling and descrambling of digital images. When a third person intercepts chaotic images, the parameters of the scrambling algorithm are secretive. Image scrambling requires that the images after scrambling should have lower intelligibility. Gu and Han [18] presented an image scrambling algorithm based on chaotic sequences. The chaotic sequence is generated using three parameters and the algorithm typically has to be iterated 100 times to generate a non-linear sequence. This introduces high complexity and the resulting scrambled image histogram is modified in the process.

Digital image scrambling cannot change the resolution of the images [19]. The images after scrambling show no difference or have no great difference from the original images and can accurately express the content or meaning of the original images [12, 20]. Compared with the traditional textual data, digital images have a greater data volume, mean that digital images have greater plain image space and scrambled image space. It is most important that autocorrelation of digital images is directly expressed in the direction of orthogonality and various angles of inclination. As a one-dimensional signal sequence, text has no autocorrelation [21]. Zhou et al. [16] proposed to consider a scrambling algorithm which is used to influence the autocorrelation of images. This is due to the worse the autocorrelation, the better the scrambling effect and the worse the intelligibility of the images after scrambling.

In this paper, two new techniques are proposed for an image scrambling algorithm based on blocks of an image and the effect on the pixel values. The first technique uses blocks of an image by scrambling the positions of the blocks of the image and the pixel values based on vertical and horizontal scrambling approaches depending on shift the rows and the columns.

**MATERIALS AND METHODS**

**The Key Mask:** The Key Mask is a one dimension array containing a set of values and the array has the same length as the secure key. The values in the key mask array are extracted from the secure key by using the Key Code Table that is fixed in the algorithm. Figure 1.1 shows the steps involved in the key mask algorithm.

**Iteration Level:** The iteration level is an integer number derived from the key mask. More iterations in the image scrambling leads to greater scrambling without a leakage problem. However, the relationship between the level of iterations and scrambling depends on the relationship between the values in the key mask. The advantage of the level of iterations is used in the scrambling phase for a great scrambling degree. Figure 1.2 shows the steps involved in the iteration level algorithm.
This algorithm is proposed to generate the key mask by using the secure key and key code table.

Algorithm Create_Key_Mask
1: Input the secure key and load key code table
2: Let length = get the secure key length
3: Let counter i = 1
4: While (counter i <= length) do
   4.1: item = get the value of the position (counter i) in the secure key;
   4.2: Let counter j = 1;
   4.3: While (counter j <= 120) do
      If (item = the value of the position (counter j) in the key code table) then
         The value in position (counter i) of the Key mask = Key code table[j].value;
      End If
      Increment counter j
   End While
   4.4: Increment counter i
End While
5: End Create_Key_Mask
6: Output: Key Mask

Fig. 1: Steps in the Key Mask Algorithm
Fig. 1: Steps in the Algorithm to the Key Mask

Scrambling Table: The scrambling table is considered as a key to the whole process for the developed algorithms. It is the output of the mathematical function of which the factors are the key mask, block size and the dimensions of the original image. The mathematical function generates the number value for all the cells of the scrambling table that are used by the scrambling algorithms to scramble the image blocks to new locations in the scrambled image. The key mask that is extracted from the secure key is used as an index to the columns of the scrambling table, the index of the columns in the original image is used as an index to the scrambling table in the vertical scrambling approach and the index of the rows in the original image is used as an index to the scrambling table in the horizontal scrambling approach. Figure 1.3 represents the algorithm to generate the scrambling table.

The combination of the mathematical function, the key mask, block size and the dimensions of the original image are used to build the scrambling table that is used to change the pixel colour values and shift or rotate the rows and the columns of the original image. The key mask and the mathematical function of this approach are used to play the main role in building the scrambling table, which is applied to generate the Scrambled image and the Scrambled image with a different number of blocks. The shifting process refers to the operation of dividing and shifting an arrangement of the original image.

Scrambling Pixel Colour Values: The algorithm is completed in two steps: the first step is block scrambling within the image using the shifting and the Scrambling technique. These techniques are explained in the next section. The second step is changing the pixel colour value (RGB) by using the scrambling pixel colour value algorithm. This process is initiated by scrambling the pixel colour value which scrambles the colour between the boundaries of the image colours according to the values in the scrambling table by using the discussed formula to prevent the problem of underflow and overflow. In this method, the RGB value of a pixel is altered, the R value of the pixel is modified to another value according to the scrambling table values. In a similar manner, the G and B values of the pixel are also changed. Figure 1.4 shows the steps involved in the scrambling pixel colour value algorithm.

Scrambling Shifting Technique: The image scrambling shifting technique involves the vertical and the horizontal movement approaches. The two approaches consist of two processes. The first process is scrambling the block positions. This is achieved by shifting the block positions between the boundaries of the original image according to the values in the scrambling table by using the proposed formula to prevent the problem of underflow and overflow. The second process is scrambling the pixel colour value which is achieved by changing (scrambling) the pixel colour values between the boundaries of the image colour according to the values in the scrambling table by using the discussed formula to prevent the problem of underflow and overflow. The main difference between these two approaches is how the block is moved and how the block position is updated within new scrambled image. In the vertical scrambling approach the block is moved from bottom to top while in the horizontal scrambling approach the block is moved from left to right [22]. An overview of the shifting technique is shown in Figure 1.5.

The shifting technique works as follows:

- Load the original image and secure key and then divide the original image into a number of blocks. Each block has the same number of pixels.
This algorithm is proposed to generate the iteration level by using the key mask.

**Algorithm Calculate_Iteration_Level (key mask)**

1: load the key mask;
2: Let length = get the key mask length, counter i = 1;
3: While (counter i ≤ length) do
   3.1: item = get the value of the position (counter i) in the key mask;
   3.2: Let iteration = 0;
   3.3: While (item > 9) do
      3.3.1: Let value = item mod 10;
      3.3.2: Let item = item div 10
      3.3.3: Let iteration = iteration + value
   3.4: End While
   3.5: Let iteration = iteration + item;
   3.6: Increment counter i
   3.7: End While
4: End Calculate_Iteration_Number
5: Output: Iteration Number

This algorithm is proposed to change the pixel colour value by using the scrambling table.

**Algorithm Scrambling Pixel_Colour_Values**

1: Load image
2: Calculate Image Width and Height
3: Let increased value = 2
4: Let H_blocks = Width/Block size
5: Let V_blocks = Height/Block size
6: Let V_blocks = Height/Block size
7: length = Calculate the length of the key mask
8: V_B_Scrambling Table (Index Of Columns in Scrambling Table) = length
9: If (H_blocks ≤ V_blocks) then
   10: H_B_Scrambling Table (Index Of Rows in Scrambling Table) = H_blocks
   Else
   11: H_B_Scrambling Table (Index Of Rows in Scrambling Table) = V_blocks
12: For i = 1 to H_B_Scrambling Table do
   13: Let value = i + increased value
   14: For j = 1 to V_B_Scrambling Table do
      15: Scrambling Value = (increased value = H_B_Scrambling Table + height) + key mask[i] +
         (increased value + 1) * V_B_Scrambling Table + width) + mask key[i] + Item Mod H_B_Scrambling Table
   16: For i = 1 to H_B_Scrambling Table do
      17: Scrambling Table (i, j) = Scrambling Value
18: Next J
Fig. 2: Steps in the Algorithm to the Iteration Level Algorithm

Fig. 3: Steps to generate the Scrambling Table

This algorithm is proposed to change the pixel colour value by using the scrambling table.

Algoritthm Scrambling Pixel_Colour_Values (Block, ValueofScramb_Table)

1: Calculate Block Width and Height;
2: For i = 1 to H_height do
3: For j = 1 to B_width do
   3.1: Block[i,j].Red = 256 + Block[i,j].Red + ValueofScramb_Table Mod 256
   3.2: Block[i,j].Green = 256 + Block[i,j].Green + ValueofScramb_Table Mod 256
   3.3: Block[i,j].Blue = 256 + Block[i,j].Blue + ValueofScramb_Table Mod 256
4: Next J
5: Next i
6: End Scrambling Pixel_Colour_Value
7: Output: New Pixels Colour Value

Fig. 4: Steps to determine the New Pixel Colour Values

Fig. 5: Overview of the Shifting Technique
Generate the key code that will be used to extract the key mask from the secure key.

Call the key mask algorithm to create the mask key table. This step is very important in the proposed processes for iteration level, scrambling table and scrambling.

Call the iteration level algorithm to generate the iteration level that can control the repetition of the scrambling processes.

Call the scrambling table algorithm to generate the scrambling table by combining the mathematical function, the width and height of original image and the number of blocks and the key mask to build the scrambling table that will be used to shift the rows and columns of the image. The key mask and the mathematical function of this approach are used to play the main role in building the scrambling table. The scrambling (shifting) process refers to the operation of dividing and shifting an arrangement of the original image.

The main idea of the scrambling process contains two steps, shifting (scrambling) the blocks and scrambling the pixel colour values.

Shifting (scrambling) the blocks of an image can be performed by shifting the blocks in the rows and the columns of the original image between the boundaries of the image according to the values in scrambling table by using the proposed formula to prevent the problem of underflow and overflow. Also, the scrambling of blocks is done by shifting all the blocks in the first row a number of times horizontally and this process of scrambling is continued until all rows are scrambled. The scrambling of the blocks is done by shifting all the blocks in the first column a number of times vertically and the scrambling process is continued until all columns are scrambled.

The shifting does not simply change the positions of the blocks but shifts all the blocks in rows a number of times depending on the scrambling table and then the same number of times for all the blocks in columns for an arrangement of blocks. For better scrambling, the block size should be small, because in that way fewer pixels will be similar to their neighbours as otherwise for an image with a high resolution, the content of such an image may be predicted by an unauthorised user who can thus guess the image.

By calling the pixel colour value algorithm, the process of scrambling the pixel colour values takes place which modifies (scrambles) the pixel colour values between the boundaries of the image colour according to the values in scrambling table by using the proposed formula to prevent the problem of underflow and overflow. In this process, the RGB value of a pixel is changed to another value according to the scrambling table values.

The relationship among the elements of the image will be decreased and thus it becomes difficult to predict the value of any given pixel from the values of its neighbours. The clear information present in an image is due to the relationship among the image elements. This perceivable information can be reduced among the image pixels using the shifting technique. Also, changing the pixel colour values can increase the level of security in the scrambled image by producing a new histogram which is different from the histogram of the original image. Thus, it becomes even more difficult to predict the value of any given pixel from the values of its neighbours.

A general block diagram of the shifting (scrambling) technique is shown in Figure 1.5.

**Experimental Details and Results:** A good quality encryption algorithm should be strong against all types of attack, including statistical and brute force attacks. Some experiments are given in this section to demonstrate the efficiency of the proposed technique. In this section, in the proposed technique, the original image is first loaded by the shifting algorithm and the Scrambling algorithm to separately build a newly Scrambled image and Scrambled image respectively with a different block sizes (1 pixel × 1 pixel, 3 pixel × 3 pixel, 10 pixel × 10 pixel) using the same iteration level (40 level). Therefore, three different Scrambled images and three different Scrambled images are obtained. The number of blocks and the block sizes in each case are shown in Table 1.

In this paper, original images are selected as shown in Figure 9 for use in this experiment.

**Correlation of Two Adjacent Pixels:** A correlation is a statistical measure of security that expresses a degree of relationship between two adjacent pixels in an image or a degree of association between two adjacent pixels in an image. The aim of correlation measures is to keep the amount of redundant information available in the encrypted image as low as possible[23]. Equation (1) is used to study the correlation between two adjacent pixels in horizontal, vertical, diagonal and anti-diagonal orientations[24].

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This algorithm is proposed to generate a shifted image using the scrambling table.

**Algorithm Create Shifted Image**

1. Load Original Image
2. Input SecureKey, Block size
3. H_Blocks = ImageWidth / Block size
4. V_Blocks = ImageHeight / Block size
5. Divide the original image into (H_Blocks * V_Blocks)
6. L_Key = Length (key mask)
7. Calculate Image Width and Height
8. Generate the Key code
9. Call the key mask algorithm (key code, SecureKey)
10. Call the iteration number algorithm (key mask)
11. Call the scrambling table algorithm (Image, Key mask, block size)
12. Repeat
13. For J = 1 to L_Key (Shift the Columns of Image)
14. IndexOfColumnsInShiftingTable = Int (Key mask(J))
15. For I = 1 to V_Blocks
16. NumberOfShift = ScramblingTable (I, IndexOfColumnsInShiftingTable)
17. Call the Shift Row algorithm (NumberOfShift, I, V_Blocks, Block size)
18. Call the Scrambling Pixel Colour Value (Block, NumberOfShift)
19. Next I
20. Next J
21. iteration = iteration - 1
22. Until (iteration > 0)
23. Output: Shifted Image

**Algorithm Shift Row**

1. For j = 1 to Image_W do
2. Shift all the blocks in the row Y (No_Shift)
3. shiftedImage(Y) = Image((J + No_Shift) mod (Image_W / Block size), Y)
4. Next j
5. End Shift Row
6. Output: Shifted Row

**Algorithm Shift Column**

1. For j = 1 to Image_H do
2. Shift all the blocks in the row X (No_Shift)
3. shiftedImage(X) = Image(X, (I + No_Shift) mod (Image_H / Block size))
4. Next j
5. End Shift Column
6. Output: Shifted Column

Table 1: Different cases of number of blocks

<table>
<thead>
<tr>
<th>Case number</th>
<th>Block size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 Pixels * 10 Pixels</td>
</tr>
<tr>
<td>2</td>
<td>3 Pixels * 3 Pixels</td>
</tr>
<tr>
<td>3</td>
<td>1 Pixels * 1 Pixels</td>
</tr>
</tbody>
</table>

Table 2 and Figure 11 summarize the correlation results of the Scrambled image and Scrambled image for all cases by using a different number of blocks with 40 iteration level. Table 2 and Figure 11 show that there is an inverse relationship between the number of blocks and the correlation. This means that increasing the number of blocks resulted in a lower correlation for all the cases by using the scrambling technique. The process of dividing and shuffling the positions of the image blocks will confuse the relationship between the original image and the scrambled image.

**Analysis of the Relationship Between the Number of Blocks and the Correlation of Scrambled Image:**

where \(x\) and \(y\) are the intensity values of two neighbouring pixels in the image and \(N\) is the number of adjacent pixels selected from the image to calculate the correlation.

\[
\rho = \frac{\sum_{i=1}^{N} (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N} (x_i - \bar{x})^2 \sum_{i=1}^{N} (y_i - \bar{y})^2}}
\]  

(1)
Fig. 9: the original images used in the experiment

<table>
<thead>
<tr>
<th>Original image</th>
<th>Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation</td>
</tr>
<tr>
<td></td>
<td>0.8346137707</td>
</tr>
<tr>
<td></td>
<td>0.806841533</td>
</tr>
<tr>
<td></td>
<td>0.947020036</td>
</tr>
</tbody>
</table>

Fig. 10: Result of Scrambled image for all the cases by using a30 Iteration level

Fig. 11: Number of blocks against Correlation value of Scrambled image
Table 2: Correlation value results of the Scrambled image for all cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of blocks</th>
<th>Correlation of Scrambled image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>30 x 30</td>
<td>0.040977</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>0.001329</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>-0.000012</td>
</tr>
<tr>
<td>Eiffel</td>
<td>30 x 30</td>
<td>-0.00001</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>0.001736</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>0.031265</td>
</tr>
<tr>
<td>Stones</td>
<td>30 x 30</td>
<td>0.047013</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>0.004003</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>0.000882</td>
</tr>
</tbody>
</table>

Table 3: Correlation Results of the Scrambled Image (Birds) using Different Iteration Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Block (1 × 1 pixel)</th>
<th>Block (3 × 3 pixel)</th>
<th>Block (10 × 10 pixel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>0.0017256</td>
<td>0.018778891</td>
<td>0.110654347</td>
</tr>
<tr>
<td>Level 10</td>
<td>0.000453668</td>
<td>0.010356657</td>
<td>0.089665322</td>
</tr>
<tr>
<td>Level 20</td>
<td>-0.000208665</td>
<td>0.007224988</td>
<td>0.078988654</td>
</tr>
<tr>
<td>Level 30</td>
<td>-0.000756221</td>
<td>0.003769666</td>
<td>0.052213451</td>
</tr>
<tr>
<td>Level 40</td>
<td>-0.000116945</td>
<td>0.001329612</td>
<td>0.040976906</td>
</tr>
</tbody>
</table>

Fig. 12: Different Iteration Levels against Correlation of Scrambled Image (Birds)

Fig. 12: Different Iteration Levels against Correlation of Scrambled Image (Birds)

the scrambled image. Also, it minimizes the relationship among image elements. Therefore, the perceivable information in the scrambled image is reduced by decreasing the correlation among the image pixels using the scrambling technique.

Analysis of the Relationship Between the Iterations Level and the Correlation of Scrambled Image for Birds Image:

Four different iteration level and three different block sizes were implemented into the scrambled image. The obtained correlation is tabulated in Table 3. This image has 40 level, the other images are extracting in different iteration level 1, 10, 20 and 30 with different block sizes 1x1 pixel, 3x3 pixels and 10 x 10 pixels.

Table 3 and Figure 12 have shown that there is an inverse relationship between the iteration level and the correlation of the scrambled image for all cases. This means that by increasing the iteration level, a lower correlation for all the cases are obtained by using the scrambling techniques. The process of scrambling the positions of the image blocks by increasing the iteration level will be increased the probability of confuses the relationship between the original image and the scrambled image. Also, it minimizes the relationship among the image elements, therefore, the perceivable information in the shifted image and rotated image is reduced by decreasing the correlation among the image pixels using the scrambling technique.

Information Entropy: Information theory is the mathematical theory of data communication and storage founded in 1949 by Shannon [25]. Information entropy is defined to express the degree of uncertainties in the system. It is well known that the entropy $H(m)$ of a message source $m$ can be calculated as:

$$H(m) = \sum_{i=0}^{2N^{-1}} P(m) \log_2 \frac{1}{P(m_i)}$$

(2)
where \( P(m) \) represents the probability of symbol \( m \) and the entropy is expressed in bits. When the messages are encrypted or scrambled, their entropy should ideally be 8. If the output of such a cipher emits symbols with entropy less than 8, there exists a certain degree of predictability which threatens its security. In order to test and evaluate the effect of the number of blocks and the iterations level of all the cases on the entropy value, different numbers of block sizes and iteration level have been used for these image cases.

**Analysis of the Relationship Between the Number of Blocks and the Entropy of Scrambled Image:** Table 4 and Figure 6 summarize the entropy value results of the Scrambled image for all cases by using a different number of blocks with different iteration level.

Table 4 and Figure 13 indicate that there is a direct relationship between the number blocks and the entropy value. This means that increasing the number of blocks results in a higher entropy value for all the cases by using the scrambling technique. The process of dividing and shuffling the positions of the image blocks will confuse the relationship between the original image and the scrambled image.

**Analysis of the Relationship Between the Iteration Level and Entropy of Scrambled Image for Eiffel Image:** Table 5 and Figure 14 illustrate the entropy results of the scrambled image against iteration level for all cases. Figure 14 illustrate the entropy values graphically. The objective of this test is to clarify the effect of iteration level on the entropy value for all cases.

Table 5 and Figure 14 indicate that the iteration level affects the entropy value when using the scrambling technique. There is a direct relationship between the entropy value and the iteration level for all cases of the scrambled images. This means that by increasing the iteration level, a higher entropy value for all the cases are obtained by using the scrambling technique.

**Image Scrambling Degree:** The scrambled image must have diffusion and confusion properties, which are the basis for designing practical ciphers. These two superior properties can be tested by computing the correlations of adjacent pixels in the scrambled image using the gray difference degree (GDD) function. To evaluate the effect of image scrambling, Ye and Li [26] introduced gray difference and gray degree of scrambling. The gray difference of a pixel with a neighbour pixel is defined as follows:

\[
GD(i, j) = \frac{1}{4} \sum_{i,j} [P(i, j) - P'(i, j)]^2
\]

where \( \{(i, j) = (i-1, j), (i+1, j), (i, j-1), (i, j+1)\} \) and \( P(i,j) \) denotes the grey value at position \( (i, j) \).

After computing the gray difference for every pixel in the image, except the pixels at the edges, the whole image’s average neighbourhood gray difference can be computed by summing and averaging:

\[
E(GD(i, j)) = \frac{\sum_{i=1}^{N-1} \sum_{j=1}^{N-1} GD(i,j)}{(N-2) \times (N-2)}
\]

The gray value degree is defined by:

\[
GDD = \frac{E(GD(i, j)) - E(GD(i, j))}{E(GD(i, j)) + E(GD(i, j))}
\]

where \( E(GD(i, j)) \) and \( E'(GD(i, j)) \) denote the average neighbourhood gray differences of the input and the scrambled images, respectively. The GDD value will be a number between -1 and 1. Better scrambling corresponds to an absolute value near 1 [20].

**Analysis of the Relationship Between the Scrambled Image and the Scrambling Techniques by Using the Scrambling Degree:** Table 6 and Figure 15 summarize the scrambling degree results of the difference between the original image and the shifted image or rotated image for all cases by using a different number of blocks with 40 iteration level.

Table 6 and Figure 15 indicate that the statistical results of the scrambling degree of scrambling techniques have a high scrambling degree. The scrambling degree in all the cases is near 1. That is means, high relationship between the scrambling technique and the scrambled image. Hence the efficiency of the scrambling techniques is high. Indicate that there is a direct relationship between the number blocks and the scrambling degree. This means that increasing the number of blocks resulted in a higher scrambling degree for all the cases by using the scrambling technique. That illustrates the security of the developed scramble methods is high. The process of dividing and shuffling the positions of the image blocks will confuse the relationship between the original image and the scrambled image.

**Analysis of the Relationship Between the Iteration Level and the Scrambled Images by Using the Scrambling Degree (Stones Image):** Tables 7 and Figure 16 summarize the scrambling degree results between the Iteration Level and the shifted image or rotated image for all cases by using a different number of blocks and a different iteration level. The objective of this test is to clarify the effect of iteration level on the Scrambled Images.
Table 4: Entropy value results of the Scrambled image for all cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of blocks</th>
<th>Entropy of Scrambled image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>30 x 30</td>
<td>7.736550</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>7.758109</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>7.785859</td>
</tr>
<tr>
<td>Eiffel</td>
<td>30 x 30</td>
<td>7.598373</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>7.745343</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>7.767353</td>
</tr>
<tr>
<td>Stones</td>
<td>30 x 30</td>
<td>7.695688</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>7.758872</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>7.79651</td>
</tr>
</tbody>
</table>

Table 5: Entropy Results of the Shifted Image (Eiffel) using different Iterations Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Block (1 x 1 pixel)</th>
<th>Block (3 x 3 pixel)</th>
<th>Block (10 x 10 pixel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>7.748436</td>
<td>7.716288</td>
<td>7.561724</td>
</tr>
<tr>
<td>Level 10</td>
<td>7.754534</td>
<td>7.724342</td>
<td>7.570423</td>
</tr>
<tr>
<td>Level 20</td>
<td>7.758965</td>
<td>7.730645</td>
<td>7.582087</td>
</tr>
<tr>
<td>Level 30</td>
<td>7.762543</td>
<td>7.737985</td>
<td>7.590883</td>
</tr>
<tr>
<td>Level 40</td>
<td>7.767353</td>
<td>7.745343</td>
<td>7.598373</td>
</tr>
</tbody>
</table>

Table 6: The Scrambling Degree Results of the Scrambled Image

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of blocks</th>
<th>Scrambling Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>30 x 30</td>
<td>0.8925</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>0.9248</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>0.9496</td>
</tr>
<tr>
<td>Eiffel</td>
<td>30 x 30</td>
<td>0.9122</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>0.9293</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>0.9596</td>
</tr>
<tr>
<td>Stones</td>
<td>30 x 30</td>
<td>0.9584</td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>0.9260</td>
</tr>
<tr>
<td></td>
<td>300 x 300</td>
<td>0.9033</td>
</tr>
</tbody>
</table>

Table 7: Scrambling Degree Results of the Scrambled Image using Different Iteration Level

<table>
<thead>
<tr>
<th>Level</th>
<th>Block (1 x 1 pixel)</th>
<th>Block (3 x 3 pixel)</th>
<th>Block (10 x 10 pixel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>0.9249</td>
<td>0.9056</td>
<td>0.8672</td>
</tr>
<tr>
<td>Level 10</td>
<td>0.9292</td>
<td>0.9092</td>
<td>0.8803</td>
</tr>
<tr>
<td>Level 20</td>
<td>0.9356</td>
<td>0.9154</td>
<td>0.8894</td>
</tr>
<tr>
<td>Level 30</td>
<td>0.9438</td>
<td>0.9203</td>
<td>0.8956</td>
</tr>
<tr>
<td>Level 40</td>
<td>0.9584</td>
<td>0.9260</td>
<td>0.9033</td>
</tr>
</tbody>
</table>

Fig. 13: Entropy value against number of blocks of Scrambled image
Fig. 14: Different Iteration Levels against Entropy of Scrambled Image (Eiffel)

Fig. 15: The Scrambling Degree Results of the Scrambled Image

Fig. 16: Iteration Level against Scrambling Degree of Shifted Image (Stones image)

Tables 7 and Figure 16 show that there is a direct relationship exists between the iteration level and the scrambling degree value of the scrambled image for all the cases, as the iteration level increases, the scrambling degree increases. This means that a higher scrambling degree results from using the developed techniques.

**Histogram Analysis:** The histogram test illustrates how pixels of the scrambled images are distributed at each colour intensity level. An image histogram can be used to measure the statistical similarity between the original image and the scrambled image. Histograms illustrate how pixels in an image are distributed by plotting the number of pixels at each intensity level. Histograms are drawn for all the blocks for different block size. It is evident from the results obtained that the block/region level histograms of the scrambled image compared to the original image is reasonably uniform and evenly spread across all possible intensity levels in the original image.
DISCUSSION

The scrambling technique have been implemented and tested to achieve the objectives of the paper. The correlation measure has been used to test and evaluate the impact of the number of blocks and the iteration level by using a scrambling technique. Experimental results of the scrambling technique showed an inverse relationship exists between the number of blocks and correlation for all cases. It has also been illustrated that there is a direct relationship between the number blocks, the iteration level and the entropy value. This means that increasing the number of blocks and the iteration level results in a higher entropy value for all the cases. Furthermore, a direct relationship exists between the number of blocks, the iteration level and the standard deviation value of the scrambled image for all the cases. As the number of blocks and the iteration level increases, the standard deviation increases. This means that a higher standard deviation is obtained by using the developed techniques. By amending the pixel colour values the statistical results of the scrambling degree of scrambling techniques have a high scrambling degree. The scrambling degree in all the cases is near 1. That is means, high relationship between the scrambling technique and the scrambled image. Hence the efficiency of the scrambling techniques is high. That illustrates the security of the developed scramble methods is high.

As a result, the process of dividing and shuffling the positions and the pixel colour values of the image blocks confuses the relationship between the original image and the scrambled image. Moreover, the perceivable information in the scrambled image has been reduced by decreasing the correlation among the image elements. Furthermore, the process of dividing and shuffling the positions of the image blocks decreases the mutual information among the scrambled image variables. As a consequence, the entropy value is increased, the standard deviation is increased, the scrambling degree is high and the scrambled image histogram is different from the histogram of the original image.

CONCLUSION

Simple and strong technique has been developed for image security using a multilevel block and pixels based on scrambling technique. The scrambling processes are used to divide the original image into a number of blocks (ex. 3 pixels by 3 pixels blocks) that are then scrambled the blocks image and the pixel colour value into original image through shift the rows and the columns and amend the pixel colour values based a scrambling table. The security measurements of the original images have highly correlated elements. This means there is a good relationship between the elements of the original images, which also have a low entropy value, a large standard deviation and high scrambling degree. The correlation between the image elements is significantly decreased and the entropy value is significantly increased by using the developed techniques. The developed technique showed that an inverse relationship exists between number of blocks, iterations level and correlation, while there is a
direct relationship between number of blocks, iterations level and entropy as well as scrambling degree. The developed technique is expected to show good performance, low correlation and high entropy, the standard deviation increases or decreases and high scrambling degree increases and the scrambled image histogram is different from the histogram of the original image.

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REFERENCES


