Raw Quick Pairs method of detecting Stego-images

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Abstract:

Du and Long[2] (2000) introduced Raw Quick Pairs detecting method of Stego-images (the images that contain the steganographic message). The underlying principle of the method is that the number of close color pairs of Stego-images will be larger compare with the number of close color pairs of normal images. In contrast, Fridrich and Goljan (2001) pointed out that RQP method only works if the number of unique colors is relatively low; and the method can not be applied to grayscale images. However, this paper will outline the core principle of RQP method; and evaluate such critical comments in details. In addition, this paper suggests potential improvement of RQP method and provides one possible alternative.

1. Introduction to Raw Quick Pairs method

1.1 The principle of the RQP method

Du and Long[2] (2000) introduced a steganalysis method that evaluates the number of close color pairs. Close color pairs means that two colors are distinguished only at Least Significant Bit. The author claims that the process of embedding messages into images will increase the number of close color pairs significantly.

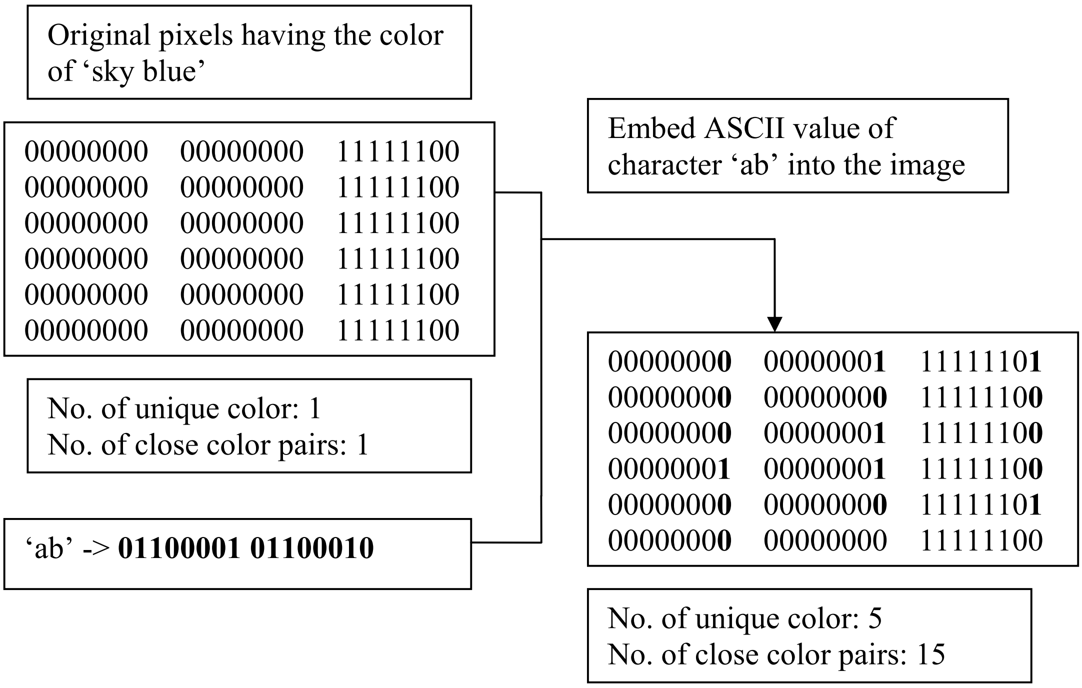

Figure 1 the process and result of embedding ‘ab’ to six ‘sky blue’ pixels

Figure 1 illustrates the process of embedding a message into images. We assume that we have six RGB pixels with ‘sky blue’ color. We then embed the ASCII value of character ‘ab’ into those pixels. The box on the bottom right shows the new values of those six ‘sky blue’ pixels. The bold bits reflect the ASCII value of ‘ab’. Each two of six new pixels become a close color pairs because Du and Long[2] (2000) defines close color pairs according to the following formulae:

$$(R_{color1}-R_{color2})^2 + (G_{color1}-G_{color2})^2 + (B_{color1}-B_{color2})2 \leq 3 \qquad (1)$$

The process of embedding two characters increases the number of unique colors five times. Moreover, the number of close color pairs is increased fifteen times compared to the original number. Therefore, we can conclude that the embedding process will increase the number of close color pairs much faster than the number of unique colors. In other word, the process will widen the gap between the number of unique colors and the number of close color pairs. Also, the more messages that are embedded into the image, the larger the gap will become. This observation forms the principle of the detection method.

1.2 Outline of the experiment

To detect the hidden message, we need to extension from the above principle. If we embed message into a stego-image, which contains some hidden information, the gap between the number of unique colors and close color pairs will not change significantly. In contrast, if we embed a new message to a normal image, which does not contain any hidden information, such gap is likely to increase. Therefore, to detect the stego-images, we embed another message into the images and compared the gap before and after the embedding process. The image will be thought of as stego-image if the gap does not change much after the embedding.

To implement experiment, we use the following formula to calculate the relative number of close color pairs.

$$R = P / (C_2^U) \qquad (2)$$

P in the above formulae is the number close pair of the image, and U is the number of unique colors of the image. C is the number of all possible combinations of U in pairs of 2. Before the experiment, we calculate the ratio of the image. During the experiment, we will embed a test message into the image. After the experiment we will re-calculate the ratio from the above formulae. If the image is a stego-image, the new ratio will not be much different from the old ratio. But if the image is a normal image, the ratio will increase significantly. Therefore, we can say those images, the ratio of which do not increase significantly after embedding the test message, very possibly contains the hidden message, and therefore needs to be further investigated.

2. Critical and appreciative evaluation of RQP method

Fridrich and Goljan[1] (2001) talked about two main drawbacks of the Raw Quick Pairs method. First, the RQP method loses its accuracy when we apply the method on images with large number of unique colors. Second, the RQP method can not be applied to the grayscale images.

2.1 Lose accuracy when applying RQP method on images with large number of unique colors

In a normal image, there are many repeat pixels which have the same exact color. For example, we have a picture with a sky background. Then a sequence of pixels has the same blue color. We call these pixels having repeat colors. If we embed a message into these pixels, the process, which changes LSB of the picture, will create many close color pairs. (The definition of close color pairs has been given in previous sections) The increment of these pairs forms the foundation of the RQP methods. However, the number of repeat colors drops significantly if we have too many unique colors. Because the distance between the two unique is large, changing the LSB of image does not create many close color pairs. (The total distances of Red, Green and Blue channel should be less than three to be thought of as close color pairs)

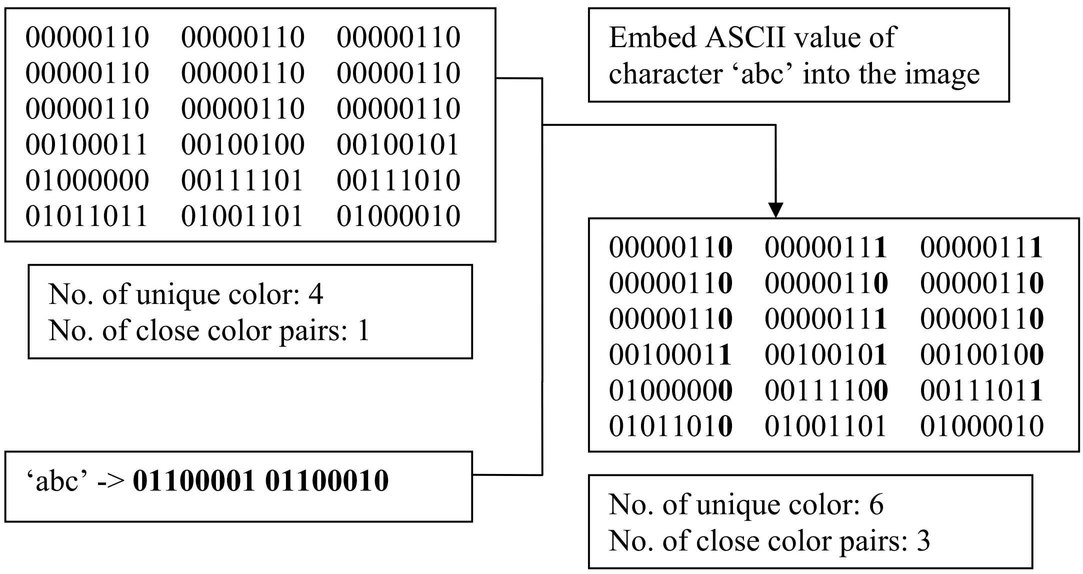

Figure 2 the process and result of embedding 'abc' to six pixels from real image

Comparing Figure 1 with Figure 2, it is obvious that the process in Figure 1 increase the number of close color pairs three times as faster as the number of unique colors; however, in Figure 2 the increasing speed of close color pairs is nearly the same as the speed of unique colors. The gap does not increase much. Both of above two processes are embedding message into image. But the results vary due to the number of unique color of original image. Figure 3 shows how the number of unique colors could affect the increment of the gap during the embedding process.

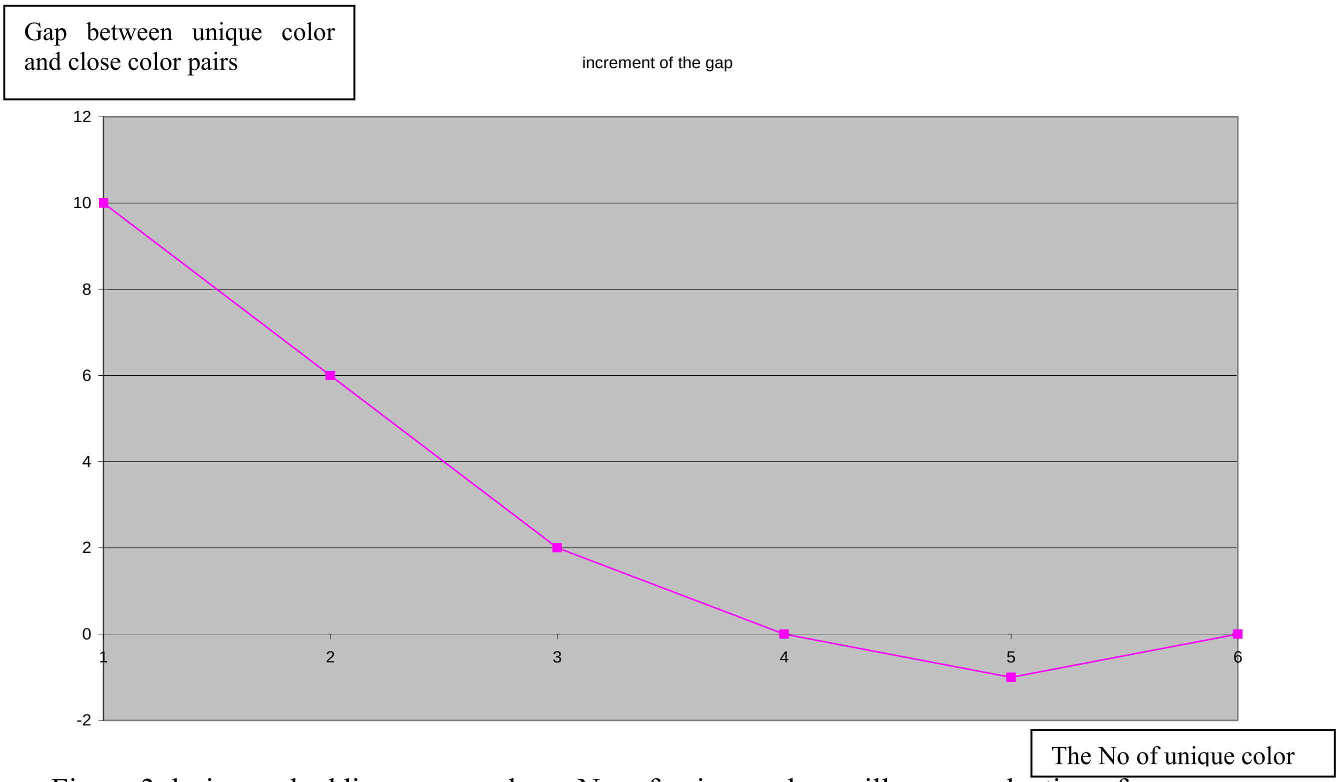

Figure 3 during embedding process, large No. of unique colors will cause reduction of the gap between unique colors and close color pairs.

Therefore, we can see that the RQP method lose its accuracy if the number of unique colors become so large.

2.2 Real-images contain large number of unique colors

It was evident that a large amount of unique colors could raise errors of the RQP method. The next question is whether the real-life images have large number of unique colors. Du and Long[2] (2000) states "The ratio of the number of unique colors to the number of pixels ranges from roughly 1:2 for high quality scans in BMP format to 1:6 …" In contrast, Fridrich and Goljan[1] (2001) disagree with the range described above; and said: "The results [of the RQP method] become progressively unreliable once the number of unique colors exceeds about 50 percent of the number of pixels. This frequently happens for high resolution raw scans and images taken with digital cameras stored in an uncompressed format [such as BMP format]". The results of my experiment show half of total scanned images contain 60% or more unique colors compare to the total number of pixels. This further illustrate that many real-life images have large number of unique colors which reduces accuracy of the RQP method.

During the experiment, I scan forty real-life photos, which is taken on my cousin's wedding day, by CANNON high-resolution scanner. Then I save the scanned images as 24-color BMP files. I then write a C# program to check the number of unique colors and the number of total pixels. Figure 4 shows the data structure of Color class which will hold the color values of pixels. Each value of RGB channel will be represented as a single byte. Figure 5 shows the method within the Color class. The method will be able to check whether two colors are exactly identical. It is the core of counting the number of unique colors.

```
public class Color {
      public byte red;
      public byte green;
      public byte blue;
      public Color (byte r,byte g,byte b)
      {
            this.red = r;
            this.green = g;
            this.blue = b;
      }
.......
}
```

Figure 4 the data structure of Color class

```
public bool checkIdentical(Color c) {
      if((this.red-c.red) != 0) return false;
      else if((this.green-c.green) != 0) return false;
      else if((this.blue-c.blue) != 0) return false;
      else return true;
}
```

Figure 5 the method of checking if two colors are identical

Percentage of unique colors	Frequency of occurrence	Percentage %	Percentile below %
100% - 90% of total pixels	0	0	100
90% - 80% of total pixels	0	0	100
80% - 70% of total pixels	0	0	100
70% - 60% of total pixels	20	50	50
60% - 50% of total pixels	12	30	20
50% - 40% of total pixels	2	5	15
40% - 30% of total pixels	6	15	0
30% - 20% of total pixels	0	0	0
20% - 10% of total pixels	0	0	0
10% - 0% of total pixels	0	0	0

Table 1 ratio of unique colors in high-resolution scan images

Table 1 indicates that half of total images have proportion of unique colors between 60% - 70%. The other thirty percent images have 50% - 60% unique colors. So there are 80% pictures having the number of unique colors more than half of the total number of pixels. The results reject the claim made by Du and Long[2] (2000) that “The ratio of the number of unique colors to the number of pixels ranges from roughly 1:2 for high quality scans in BMP format to 1:6 …” In fact, there are only 20% of total images in the range from 1:6 to 1:2. Thus, the results of the study reveal that many high resolution scanned images have large number of unique colors. This will weaken the RQP method.

2.3 Extended RQP method could be applied on grayscale images

Although the RQP method is originally designed to deal with 24-color bit map images, the method can be extended to deal with grayscale images. The claim that the RQP cannot be applied to grayscale images made by Fridrich and Goljan[1] (2001) is not necessarily true. Formula (1) shows the original method of calculating the distance of 24-color bit map images. The formula sums up the distance of three channels of Red, Green and Blue. Instead of having three bytes to represent the color of a pixel, the grayscale image has one byte to represent the color. Therefore, we can modify the formulae without interrupt the principle of the RQP method. The modified formula is shown below:

$$(COLOR_1 - COLOR_2)^2 \leq 1 \qquad (3)$$

Other essential elements, such as the number of unique colors, to conduct RQP experiment still exist in the grayscale images. First, the grayscale images have reasonable amount of unique colors. Second, changing the LSB of each pixel byte will increase the close color pairs according to the formulae (2).

To prove my hypothesis, we conduct the experiment to prove our hypothesis that RQP method still works for detecting stego-images.

	Ratio before embed test message	Ratio after embedded test message	Percentage of change	Stego-Image
1	0.034	0.034	0.000	Yes
2	0.022	0.024	8.696	No
3	0.029	0.039	33.333	No
4	0.028	0.038	34.375	No
5	0.016	0.018	11.628	No
6	0.019	0.022	15.625	No
7	0.015	0.017	14.286	No
8	0.018	0.017	-6.452	Yes
9	0.026	0.030	15.789	No
10	0.013	0.015	20.513	No
11	0.023	0.032	39.394	No
12	0.023	0.030	31.429	No
13	0.020	0.023	18.868	No
14	0.013	0.028	111.765	No
15	0.034	0.046	36.842	No
16	0.015	0.017	12.000	No
17	0.026	0.026	0.000	Yes
18	0.018	0.023	26.786	No
19	0.015	0.021	35.000	No
20	0.038	0.065	68.421	No
21	0.013	0.033	155.556	No
22	0.015	0.015	-1.190	Yes
23	0.016	0.019	15.000	No
24	0.022	0.025	10.811	No
25	0.021	0.027	27.778	No
26	0.035	0.044	26.087	No
27	0.038	0.050	31.579	No
28	0.016	0.015	-3.846	Yes
29	0.018	0.023	25.000	No
30	0.027	0.043	57.143	No

Table 2 the results of experiment on grayscale images

Table 2 shows the results of testing thirty grayscale images with RQP method. There are five pre-defined stego-images indicated in the last column. The percentage of change (the fourth column) is close to zero for those five images because the ratio of close color pair does not change much for the stego-image. (The idea is illustrated in the previous section)

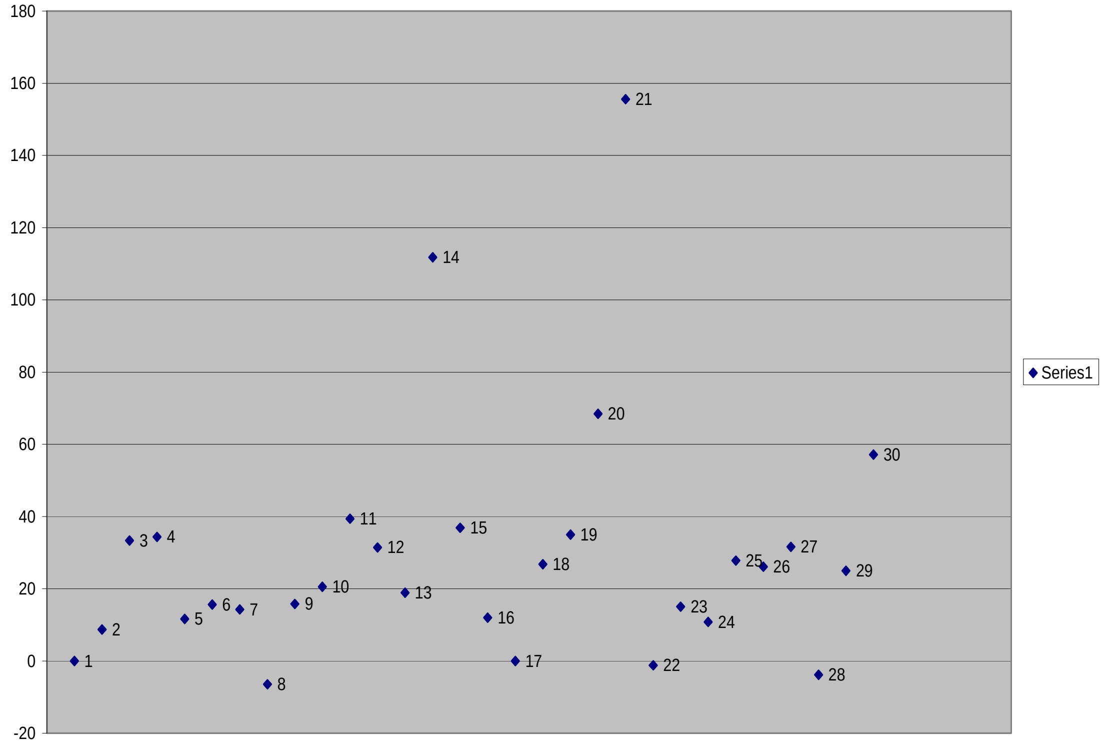

Figure 6 the point chart of experiments on grayscale images

As mentioned earlier, after we embed a test message by using the RQP method, it was expected that the percentage of unique colors increase significantly for those normal images. However, the percentage of unique colors for those stego-images will remain constant with minor change. Such change is negligible. In Figure 6, it shows that all the pre-defined stego-images fall on zero change or below. Therefore, it is obvious that these images are stego-images. This falls in line with what is expected by the outline of the experiment. Thus far, the hypothesis that the RQP method will work well on grayscale images has been well supported by the experiment.

2.4 Avoid detection by RQP method

Apart from above two criticisms noted by Fridrich and Goljan[1] (2001), I have a further criticism. The RQP method does not work if we only embed message into those pixels that have unique color. In another word, we do not change LSB of repeat colors. Thus, the embedding process will not create many close color pairs, which is the essence of the RQP method. Although this will reduce the steganographic capacity of the image, it does prevent the stego-image being caught by RQP method. Again, the RQP method is based on the assumption that embedding bits into LSB of repeating color pixels will increase the number of close color pairs. The increment of close color pair indicates that the image contains hidden message. This increase of close color pair disappears if we only embed the message into the pixels having unique color. Eventually, the method fails to detect such stego-images.

3. An alternative detection method — Visual Attack

Westfeld and Pfitzmann[3] (2000) introduced a visual attack which can detect the place of the hidden message by human's eye with the aid of computer program. If the method is feasible, it can be used as complementary to RQP method. Especially, when the RQP method fails due to the drawback described in the previous section.

Visual attach challenges the claim "Note that for most images the LSB plane is essentially random and doesn't contain any easily recognizable structure." made by Fridrich and Goljan[1] (2001). Westfeld and Pfizmann[3] (2000) believe that the LSB has a kind of pattern rather than complete random. But the message embedding process will thoroughly randomize the LSB of an image. This forms the principle of visual attack.

The visual attack will remove the cover information of an image and extract the potential message information. This process varies from one image type to another. After extracting the potential message information, we can perform the visual attack to see if such information looks random. If it looks random, then we think it a stego-image. If it still has a kind of pattern, it is a normal image.

Figure 7 Experimentation results of visual attack

Figure 7 shows three images. Most left one is the original picture. Center and most right images are the steganographic value extracted from the original image. The difference is that we did not embed any information into the center image, but we embed large amount of information into the most right images. It seems that the center image has a kind of pattern while the most right one is totally randomized.

Although the argument whether the LSB of an image is random continues these days, at lease LSB of some images have a kind of pattern, which we can take advantage with to make the visual attack. However, to make visual attack more convincible, the author needs to provide more experimental results that show LSB of most images have a kind of pattern.

Reference:

1. Fridrich, J. Goljan, M. & Du, R. (2001). Detecting LSB steganography in color and gray-scale images. *Multimedia IEEE, 8(4),* 22-28.
2. Fridrich, J. Long, M. & Du, R. (2000). Steganalysis of LSB encoding in color images. *Multimedia And Expo 2000 ICME 2000 IEEE International Conference On, 3,* 1279-1282.
3. Westfeld, A., & Pfitzmann, A. (2000). Attacks on steganographic systems. *Lecture Notes In Computer Science, 1768,* 61-75.