Pixel Processing Analysis in QR Code Visual Cryptography

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***Abstract*—Visual cryptography is a cryptography technique that can reveal it's contents only using the human vision. This technique has been applied to encryption of QR codes, although the configuration of the creation of it's share images has not been discussed before. Pixel processing of QR code visual cryptography is analyzed based on the subpixel matrix and the pixel matrix patterns used.**

Keywords—QR code, visual cryptography, pixel matrix

I. INTRODUCTION

QR Codes have been a big part of humanity today. People can easily access information contained within by only scanning it with a QR app using the camera. This ease of access also creates a potential threat of exploitation and breach of data. Information within the QR code can be easily retrieved and stolen as long as the image exists. One of the options to protect the existence of the QR code is to encrypt it in such a way so that it is no longer recognizable by the QR app as a QR code. An alternative is to split the QR code into multiple images which when a certain number of images is stacked the QR code will be revealed.

The method above is called Visual Cryptography which is generating multiple images based on an original image called shares. When n shares are combined and stacked on top of each other, the original image will be revealed. The n value and the number of shares created is decided beforehand. The paper "Secure QR Code Scheme Based on Visual Cryptography" [1] defines a visual cryptography method by creating 2 shares which it's pixel values are determined by a pseudo-random matrix. A potential analysis topic is the pixel subdivision used in the paper: it is described that 1 pixel is divided into a 4x4 matrix and randomly transformed into it's corresponding matrix (black or white). Another one that comes to mind is the matrix's pattern which is a checkered pattern; other patterns might result in a different QR code quality. This paper proposes an analysis on pixel processing of QR code visual cryptography and each factor's performance on the quality of the QR code.

II. VISUAL CRYPTOGRAPHY

Visual cryptography is a cryptographic technique to encrypt visual information such as text and pictures to multiple images and can be decrypted only by the naked eye This technique is found by M. Naor and A. Shamir in 1994 by defining the k out of n secret sharings problem. The information to be encrypted called the secret image is split into multiple images called shared images. These shared images does not mean anything on it's own, but when multiple shared images are stacked on top of another, the secret image will be revealed and can be seen by the receiver.

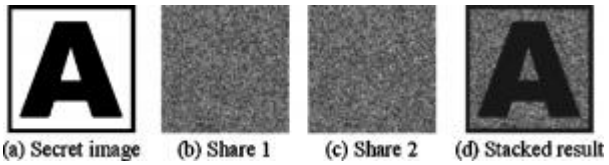

Figure 1 Example of visual cryptography

Shared images are created by dividing the secret image pixels into subpixels and randomly assigning a pixel matrix from a set of pixel matrices as the subpixels to a corresponding pixel of the secret image. This will create a noisy image that does not resemble anything, thus concealing the information. The pixel matrices are predetermined combinations of black and white pixels that resembles a noisy segment. To differentiate between a black and white pixel of the secret image, the 2 pixel matrix for each shares are determined such as that when both shares are stacked, a segment portraying a black pixel will be fully black, while a segment portraying a white pixel will only be partly black. The pixel matrix usually has a size of 2-4 elements, thus the resulting share image will have a size of 2-4 times of the secret image.

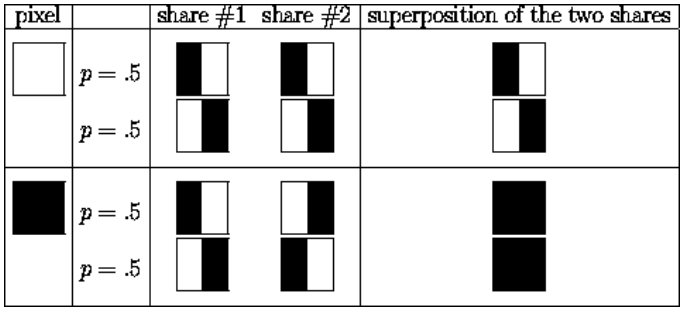

Figure 2 Share segment determination in visual cryptography

To retrieve the secret image, the receiver must stack the share images and view the resulting image created from the combination of both share images. The secret image obtained this way is usually blurrier and has less quality compared to the original secret image. This is caused by each original secret pixel image is presented by multiple pixels in the share images, thus skewing the image.

III. PIXEL PROCESSING

The problem with QR code visual cryptography is that the resulting secret image is sometimes unreadable by the scanner. In this paper, pixel processing for the creation of the share images is analyzed and tested to see which configuration produces the best secret image. Pixel processing is divided into 2 segments, which are the number of subpixels and patterns of the pixel matrices. Subpixels are divided into 3 categories which are 2x2, 3x3, and 4x4 matrix. Patterns of the pixel matrices are divided into 4 variations which are horizontal striped, vertical striped, checkered, and mixed where all the other variations are available to be randomly chosen. This experiment will use 5 different QR codes, each differing in it's complexity:

Figure 3 QR Code 1

Figure 4 QR Code 2

Figure 5 QR Code 3

Each configuration will result in 5 different QR codes which will be tested by scanning it with a QR code reader. The used QR code reader application is the QR Code Reader app on the Android.

A. 2x2 Matrix

1. Horizontal Striped

The pixel matrices are as follows:
(1,1,0,0), (0,0,1,1)
And these are the resulting secret images after the share images are stacked:

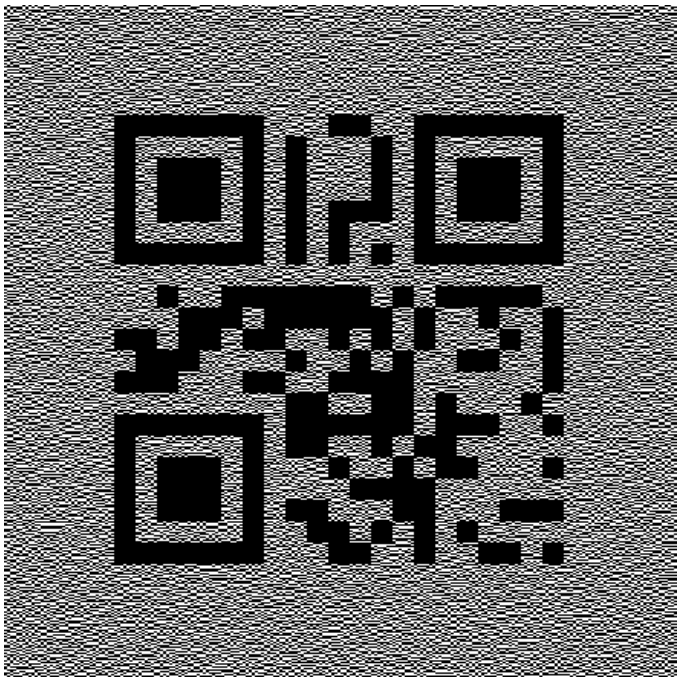

Figure 6 QR Code 1: Horizontal Striped, 2x2 Matrix

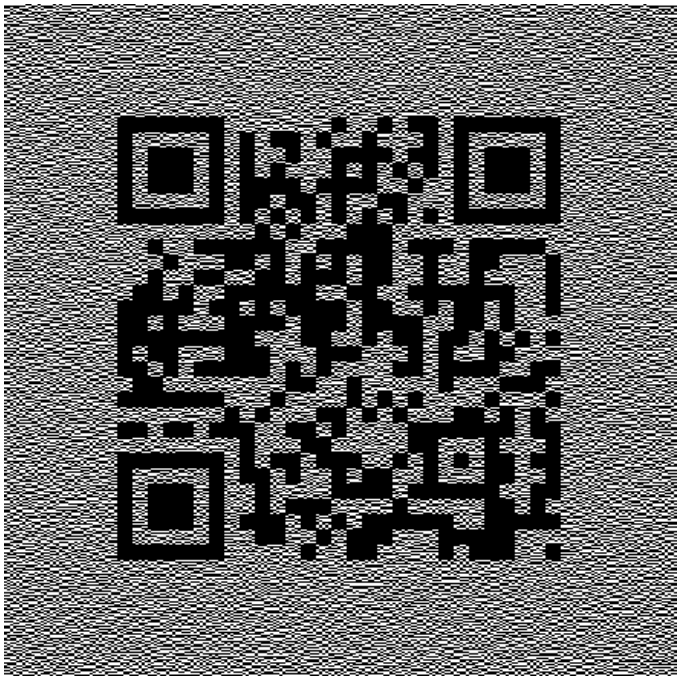

Figure 7 QR Code 2: Horizontal Striped, 2x2 Matrix

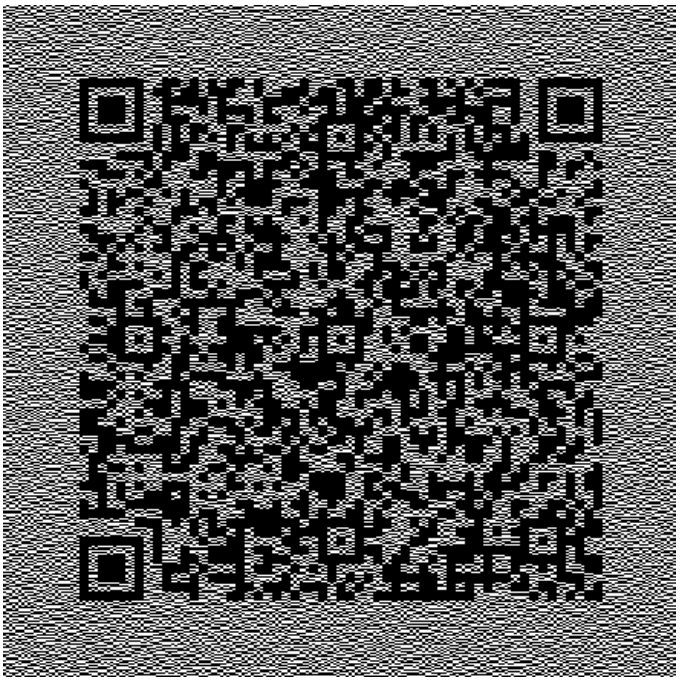

Figure 8 QR Code 3: Horizontal Striped, 2x2 Matrix

2. Vertical Striped

The pixel matrices are as follows:
(1,0,1,0), (0,1,0,1)
And these are the resulting secret images after the share images are stacked:

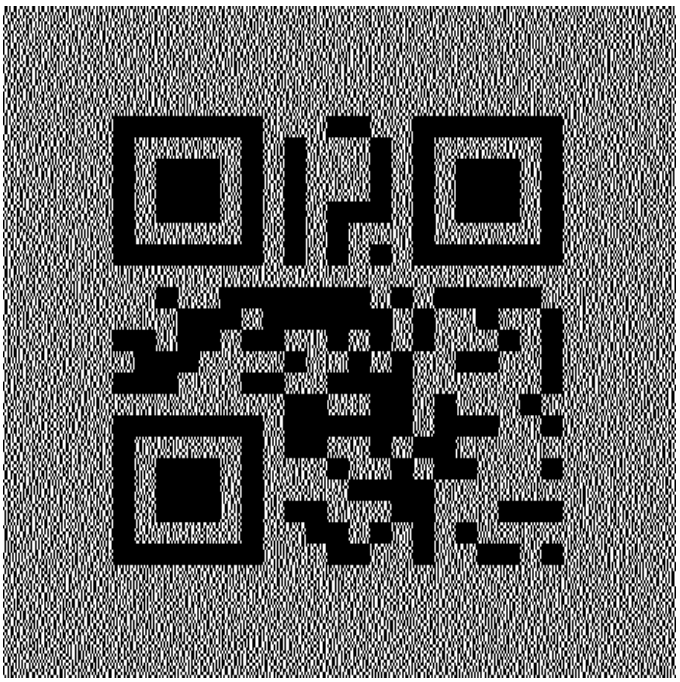

Figure 9 QR Code 1: Vertical Striped, 2x2 Matrix

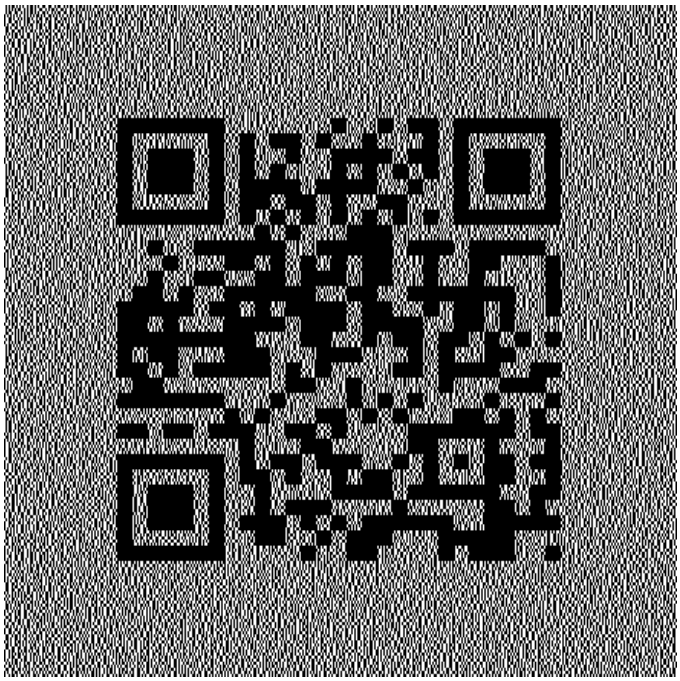

Figure 10 QR Code 2: Vertical Striped, 2x2 Matrix

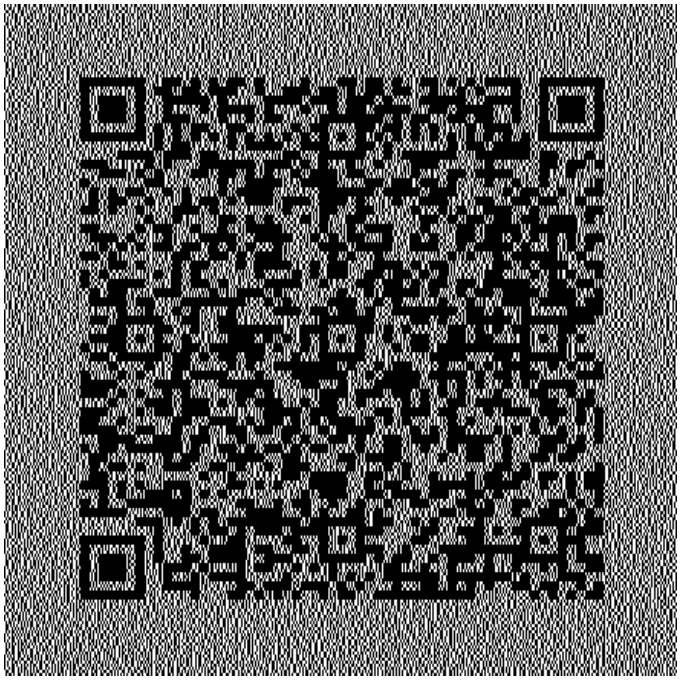

Figure 11 QR Code 3: Vertical Striped, 2x2 Matrix

3. Checkered

The pixel matrices are as follows:
(1,0,0,1), (0,1,1,0)
And these are the resulting secret images after the share images are stacked:

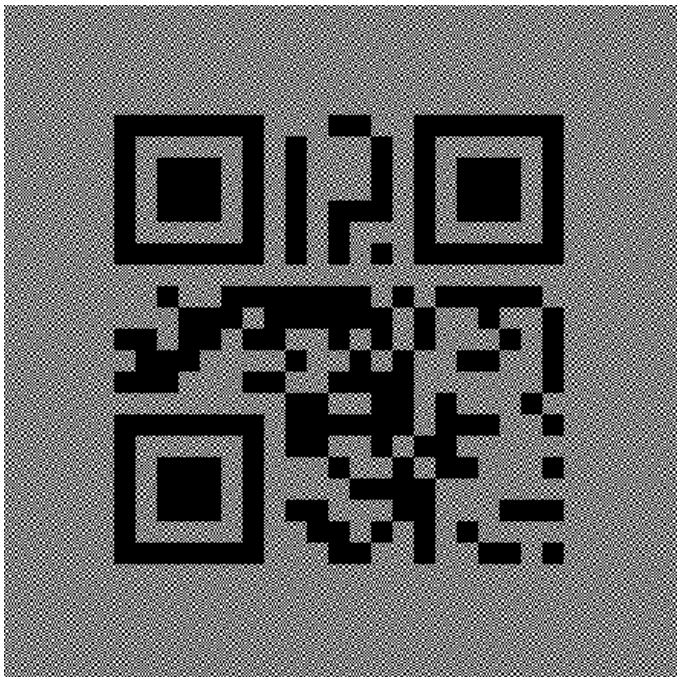

Figure 12 QR Code 1: Checkered, 2x2 Matrix

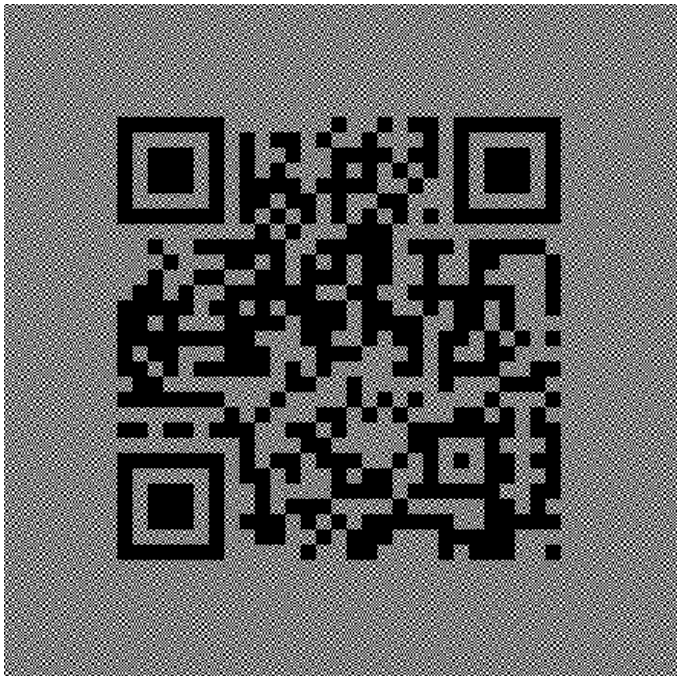

Figure 13 QR Code 2: Checkered, 2x2 Matrix

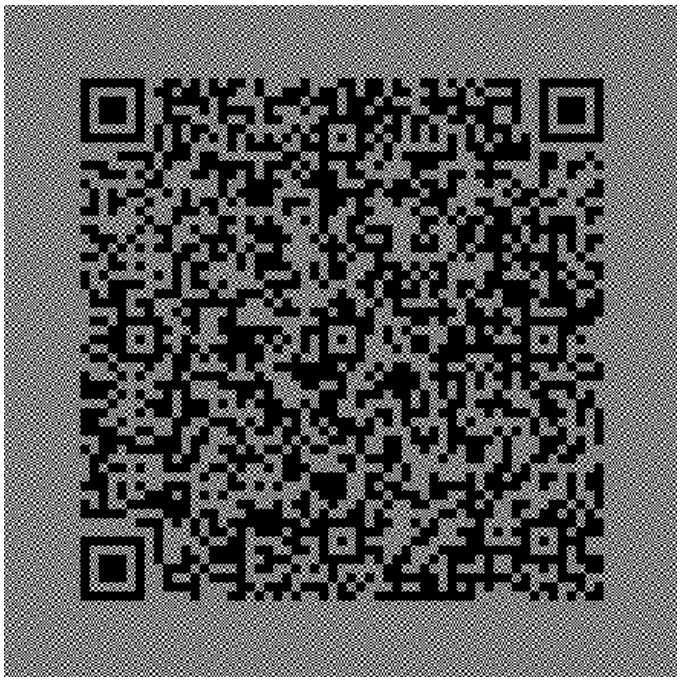

Figure 14 QR Code 3: Checkered, 2x2 Matrix

4. Mixed

The pixel matrices are as follows:
(1,1,0,0), (1,0,1,0), (1,0,0,1), (0,1,1,0), (0,1,0,1), (0,0,1,1)
And these are the resulting secret images after the share images are stacked:

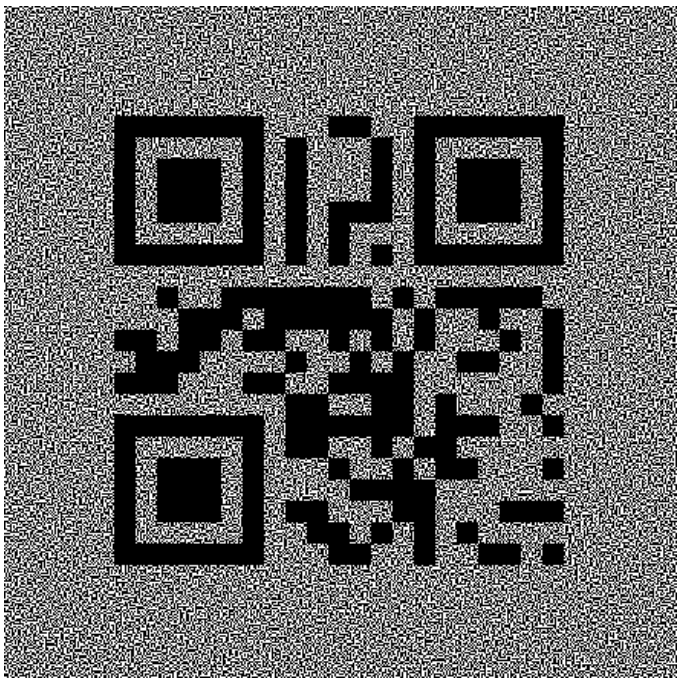

Figure 15 QR Code 1: Mixed, 2x2 matrix

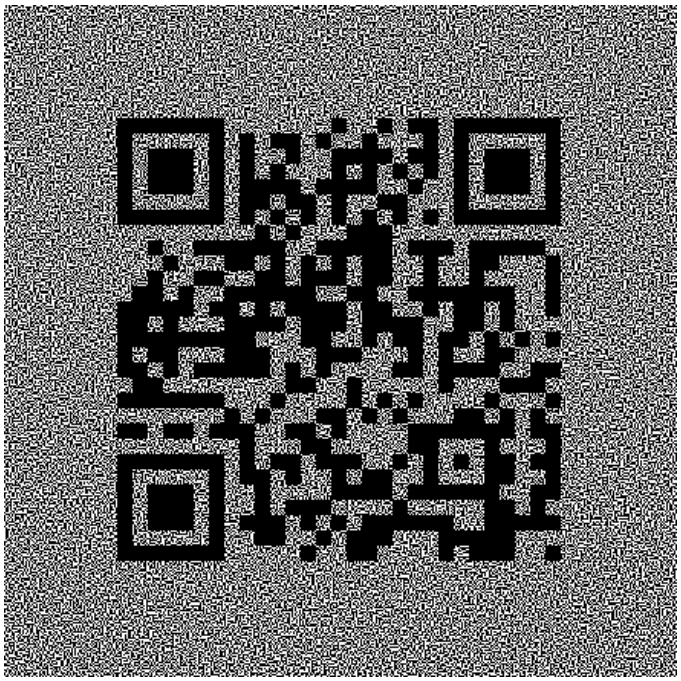

Figure 16 QR Code 2: Mixed, 2x2 Matrix

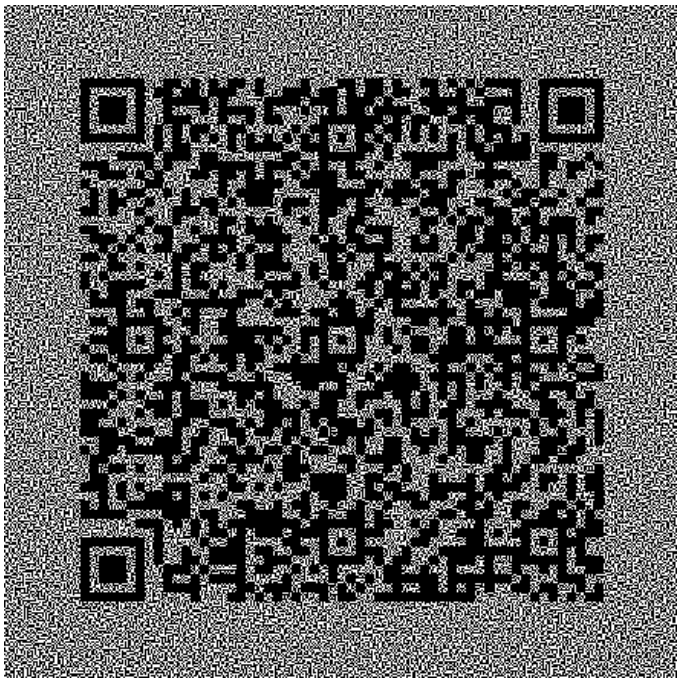

Figure 17 QR Code 3: Mixed, 2x2 Matrix

For all 12 QR codes, the resulting secret image can be successfully scanned and read by the QR code scanner. Note that the checkered pattern has a smoother background compared to the horizontal and vertical pattern whereas the mixed pattern's background smoothness is between the two.

B. 3x3 Matrix

1. Horizontal Striped

The pixel matrices are as follows:
(1,1,1,0,0,0,1,1,1), (0,0,0,1,1,1,0,0,0)
And these are the resulting secret images after the share images are stacked:

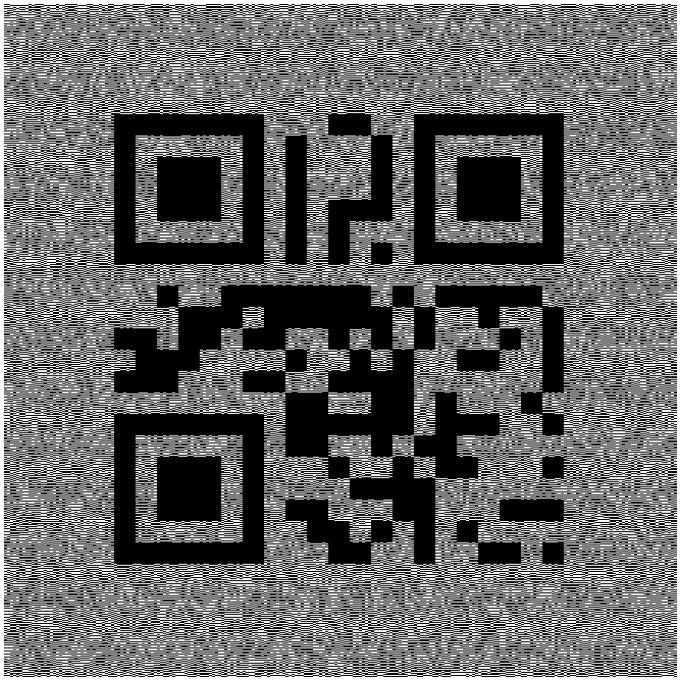

Figure 18 QR Code 1: Horizontal Striped, 3x3 Matrix

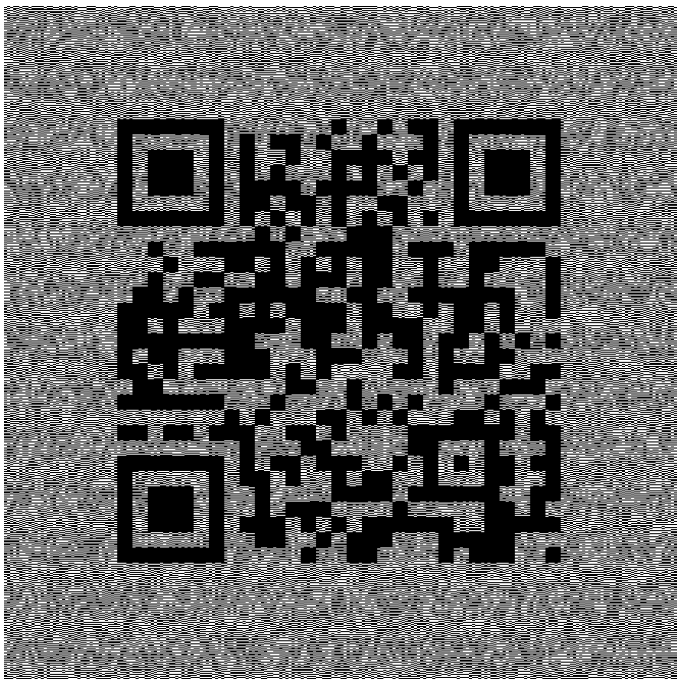

Figure 19 QR Code 2: Horizontal Striped, 3x3 Matrix

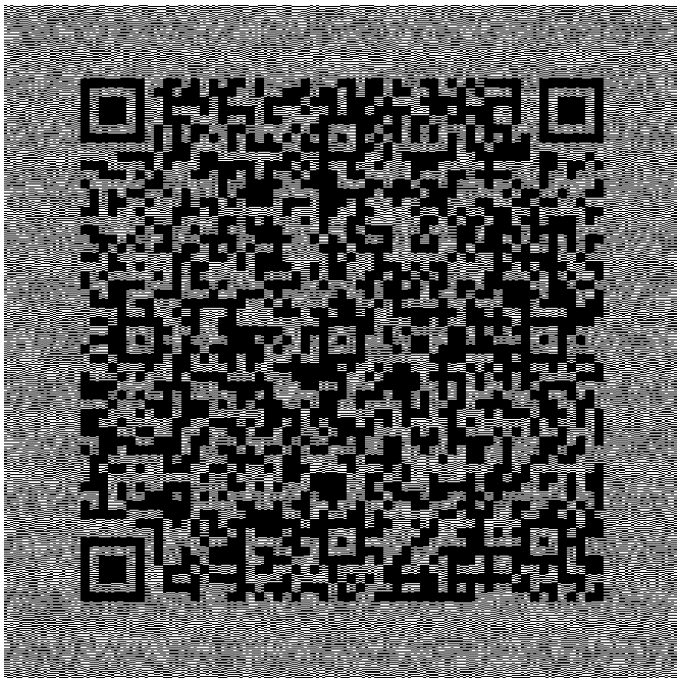

Figure 20 QR Code 3: Horizontal Striped, 3x3 Matrix

2. Horizontal Striped

The pixel matrices are as follows:
(1,1,1,0,0,0,1,1,1), (0,0,0,1,1,1,0,0,0)
And these are the resulting secret images after the share images are stacked:

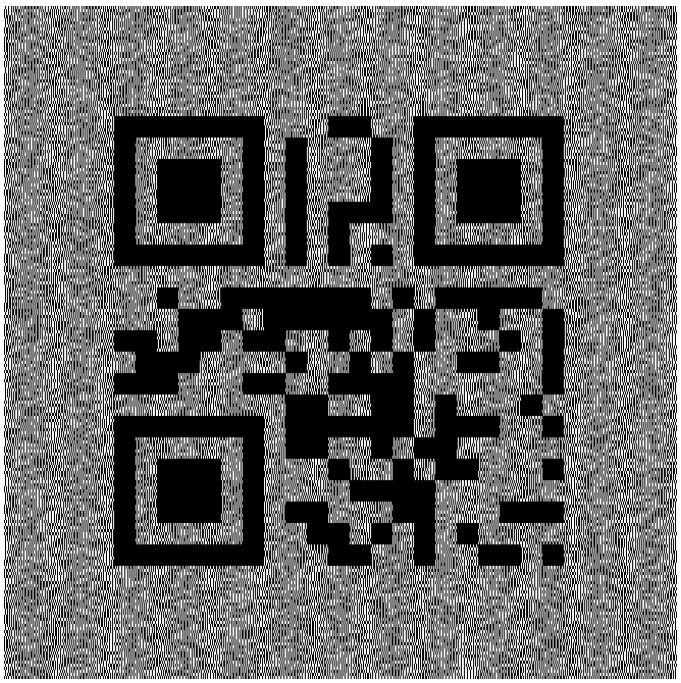

Figure 21 QR Code 1: Vertical Striped, 3x3 Matrix

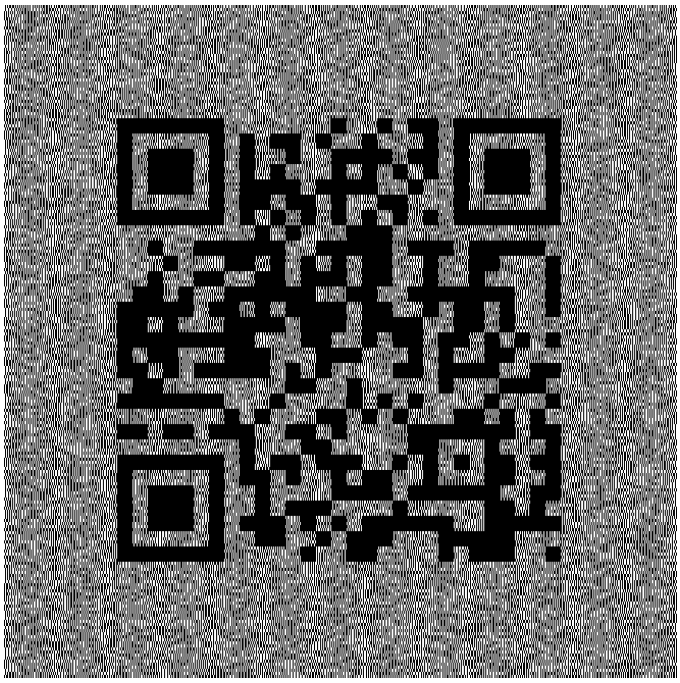

Figure 22 QR Code 2: Vertical Striped, 3x3 Matrix

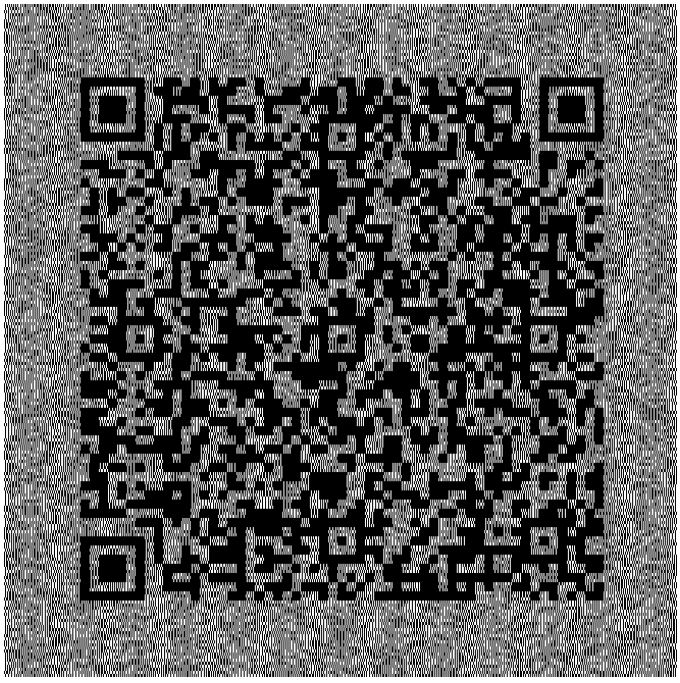

Figure 23 QR Code 3: Vertical Striped, 3x3 Matrix

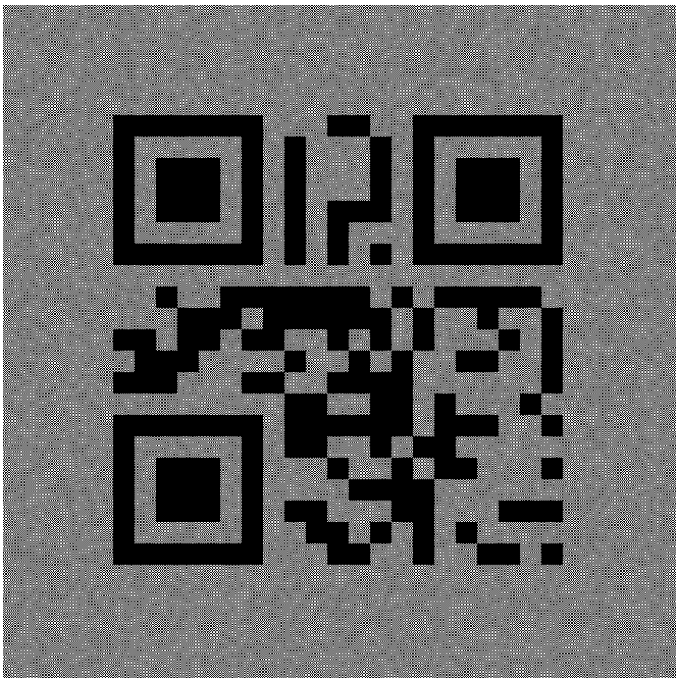

Figure 24 QR Code 1: Checkered, 3x3 Matrix

Figure 25 QR Code 2: Checkered, 3x3 Matrix

3. Horizontal Striped

The pixel matrices are as follows:
(1,1,1,0,0,0,1,1,1), (0,0,0,1,1,1,0,0,0)
And these are the resulting secret images after the share images are stacked:

Figure 26 QR Code 3: Checkered, 3x3 Matrix

4. Mixed

The pixel matrices are as follows:
(1,1,1,0,0,0,1,1,1), (0,0,0,1,1,1,0,0,0), (1,0,1,1,0,1,1,0,1), (0,1,0,0,1,0,0,1,0), (1,0,1,0,1,0,1,0,1), (0,1,0,1,0,1,0,1,0)
And these are the resulting secret images after the share images are stacked:

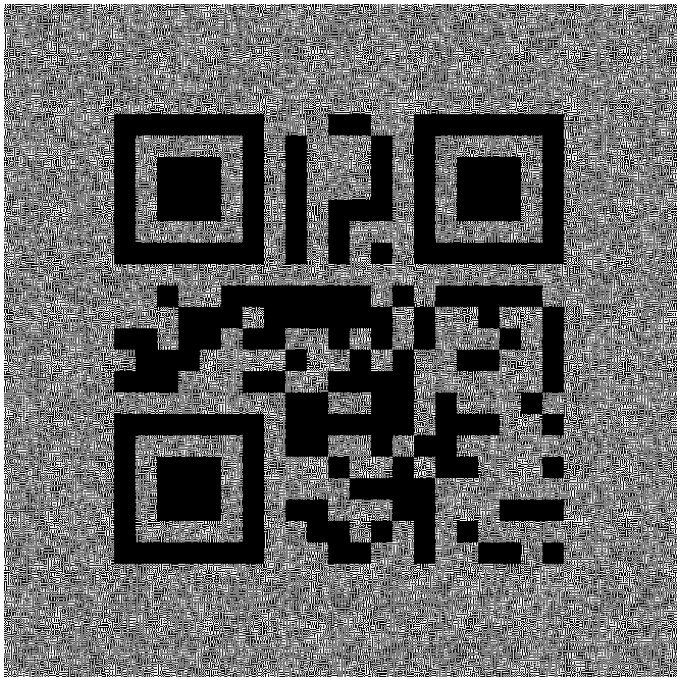

Figure 27 QR Code 1: Mixed, 3x3 Matrix

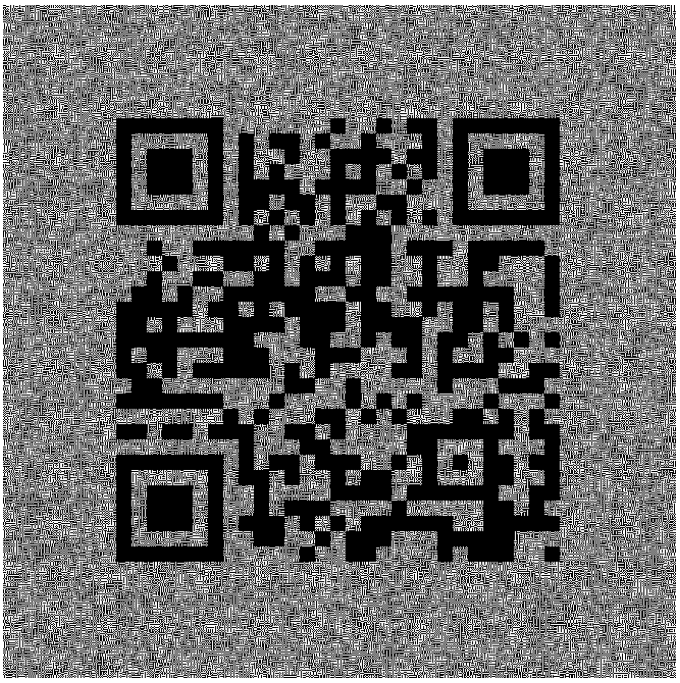

Figure 28 QR Code 2: Mixed, 3x3 Matrix

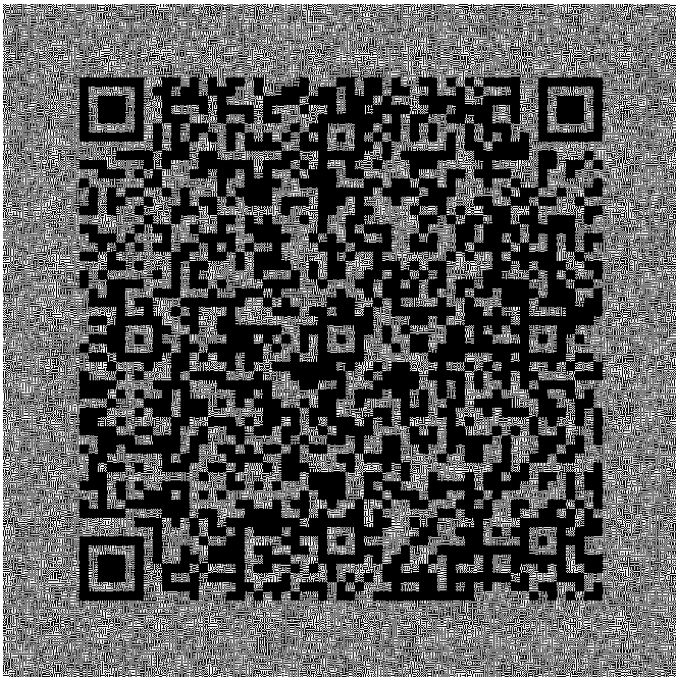

Figure 29 QR Code 3: Mixed, 3x3 Matrix

For all 12 QR codes, the resulting secret image can be successfully scanned and read by the QR code scanner. Note that the checkered pattern also has a smoother background compared to the horizontal and vertical pattern, similar to the 2x2 matrix subpixel. The difference is that the coarseness of the mixed pattern is now somewhat the same as the horizontal and vertical patterns.

C. 4x4 Matrix

1. Horizontal Striped

The pixel matrices are as follows:
(1,1,1,1,0,0,0,0,1,1,1,1,0,0,0,0),
(0,0,0,0,1,1,1,1,0,0,0,0,1,1,1,1)
And these are the resulting secret images after the share images are stacked:

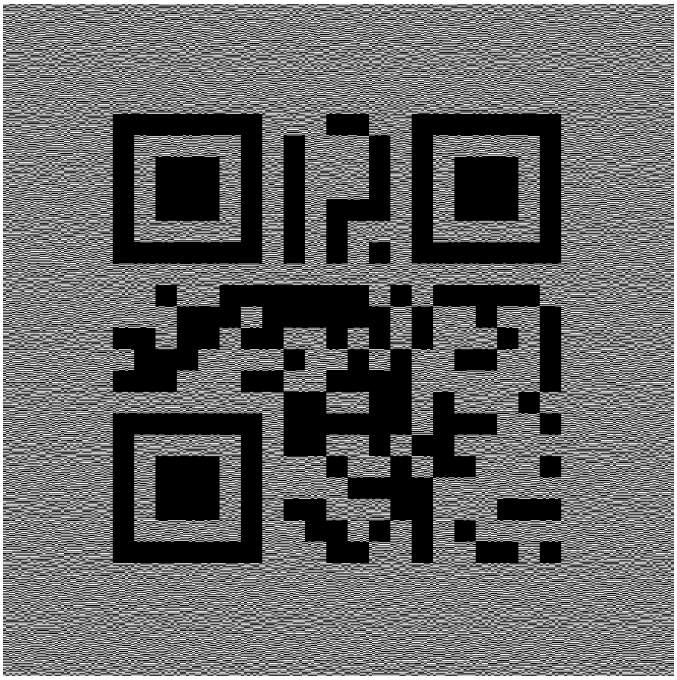

Figure 30 QR Code 1: Horizontal Striped, 4x4 Matrix

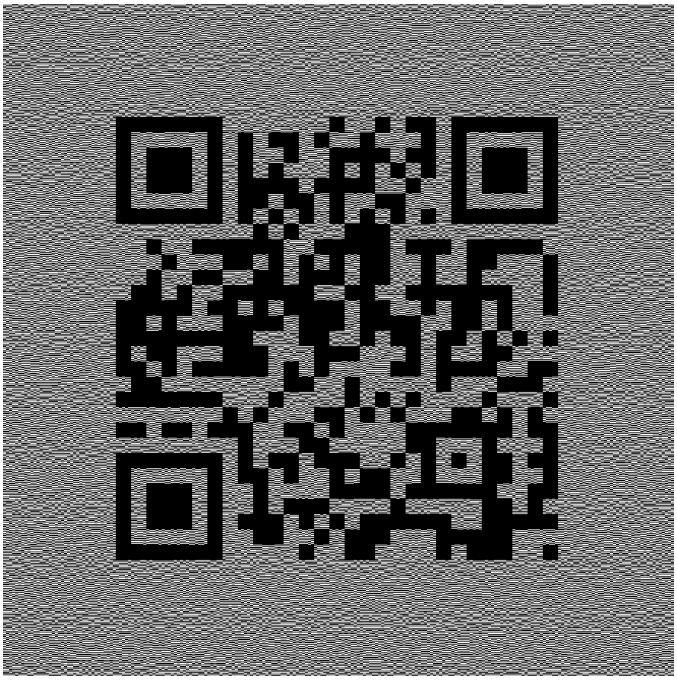

Figure 31 QR Code 2: Horizontal Striped, 4x4 Matrix

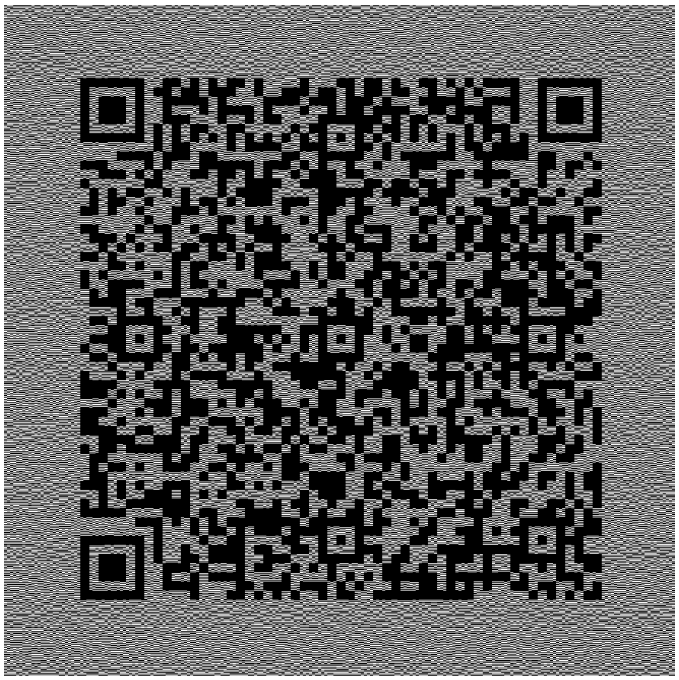

Figure 32 QR Code 3: Horizontal Striped, 4x4 Matrix

2. Vertical Striped

The pixel matrices are as follows:
(1,1,1,1,0,0,0,0,1,1,1,1,0,0,0,0),
(0,0,0,0,1,1,1,1,0,0,0,0,1,1,1,1)
And these are the resulting secret images after the share images are stacked:

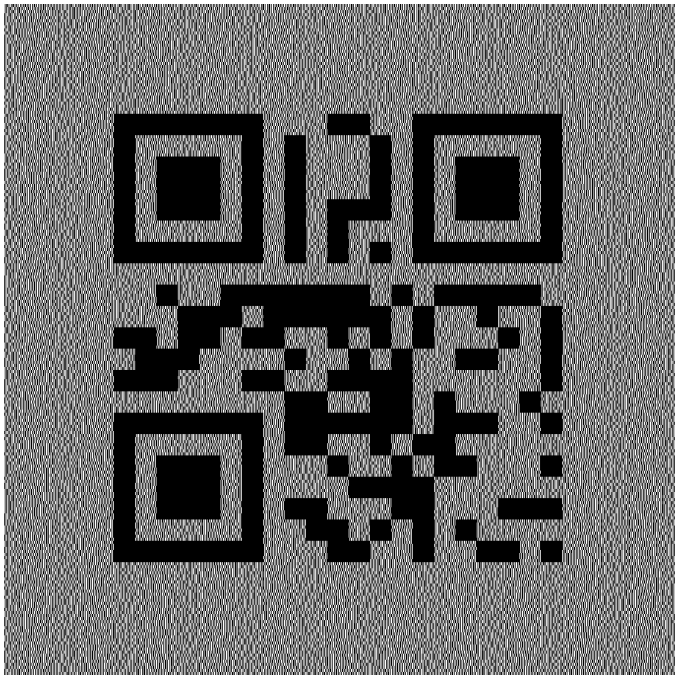

Figure 33 QR Code 1: Vertical Striped, 4x4 Matrix

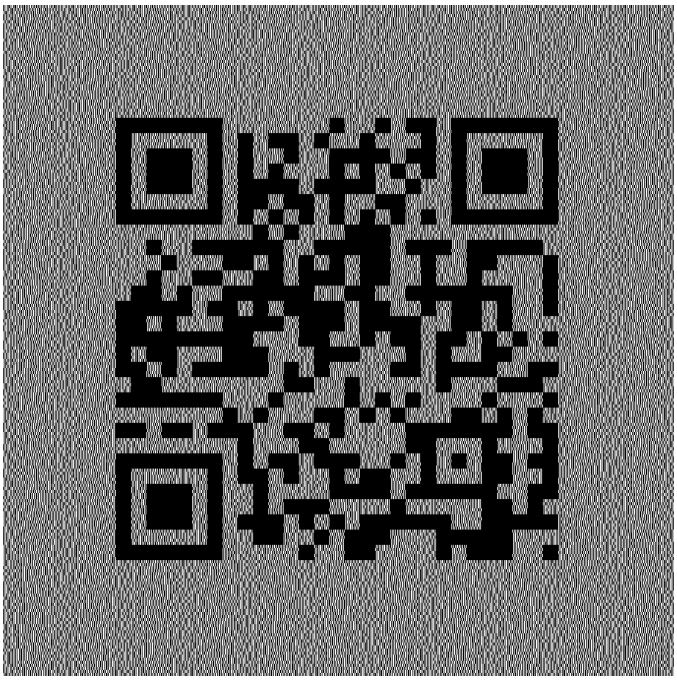

Figure 34 QR Code 2: Vertical Striped, 4x4 Matrix

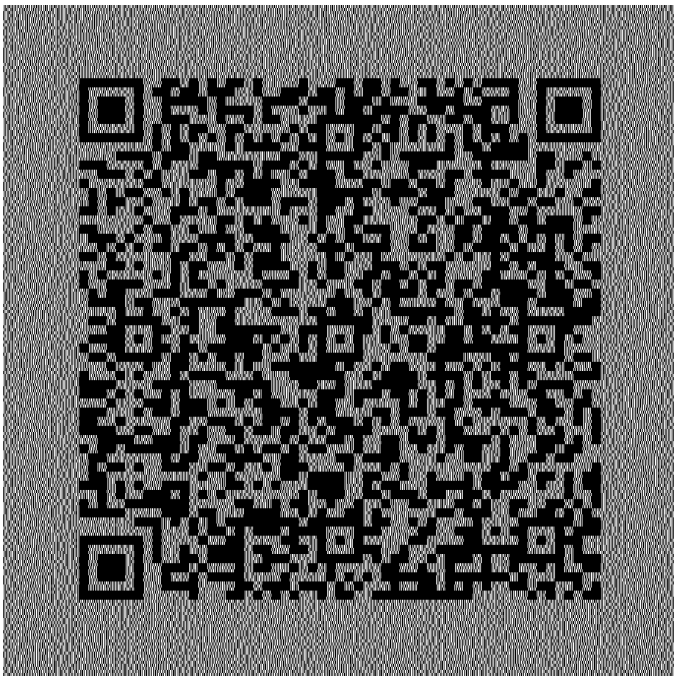

Figure 35 QR Code 3: Vertical Striped, 4x4 Matrix

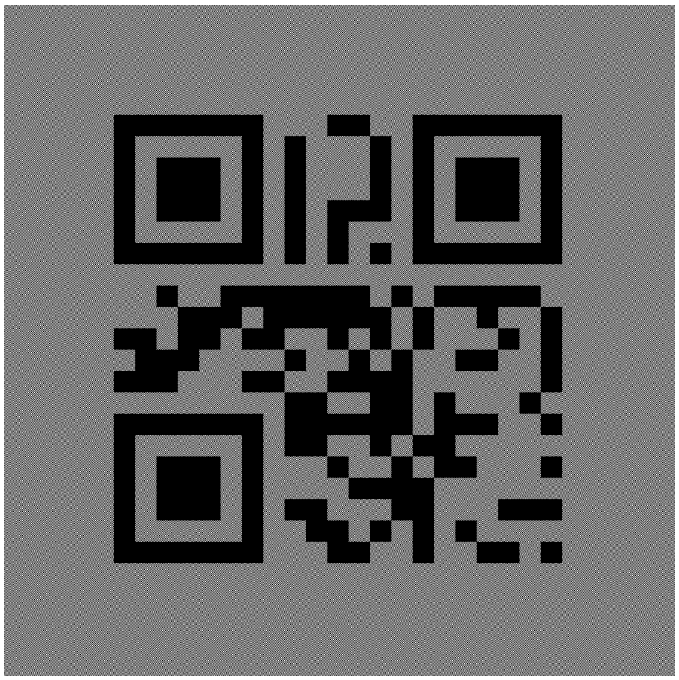

Figure 36 QR Code 1: Checkered, 4x4 Matrix

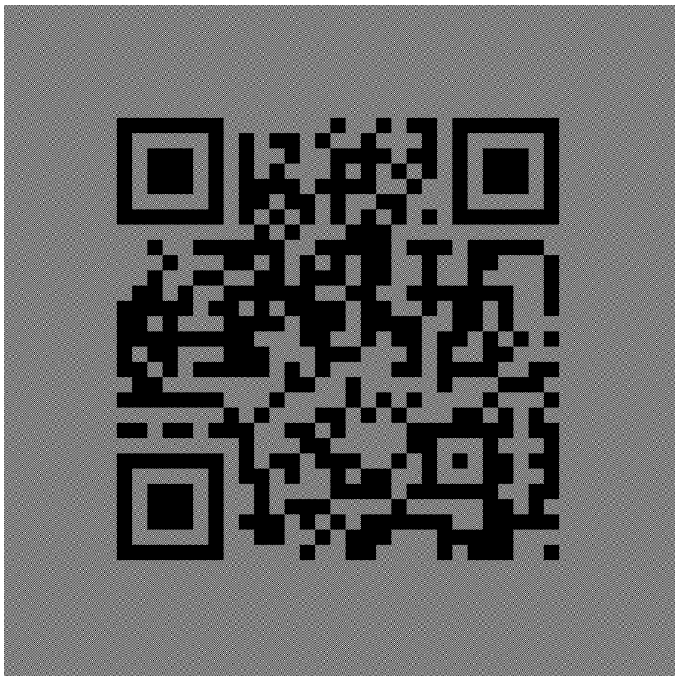

Figure 37 Figure 36 QR Code 2: Checkered, 4x4 Matrix

3. Checkered

The pixel matrices are as follows:
(1,1,1,1,0,0,0,0,1,1,1,1,0,0,0,0),
(0,0,0,0,1,1,1,1,0,0,0,0,1,1,1,1)
And these are the resulting secret images after the share images are stacked:

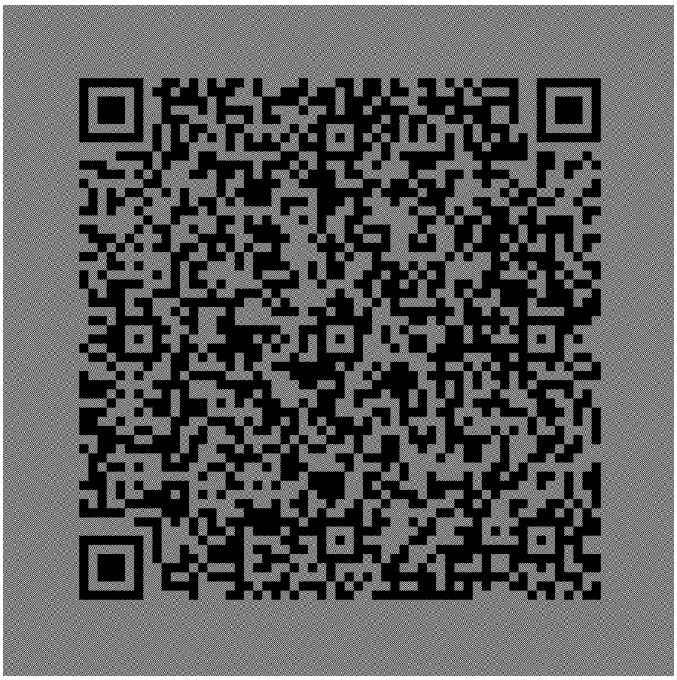

Figure 38 Figure 36 QR Code 3: Checkered, 4x4 Matrix

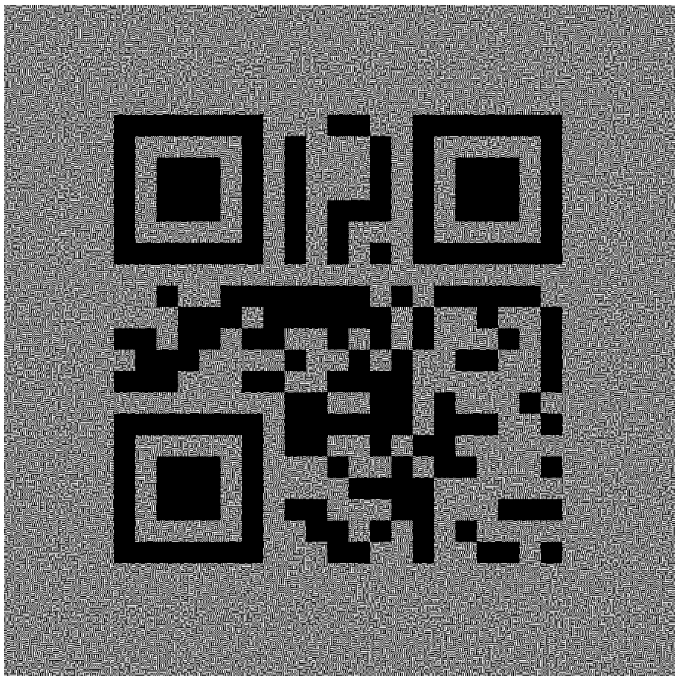

Figure 39 QR Code 1: Mixed, 4x4 Matrix

4. Mixed

The pixel matrices are as follows:
(1,1,1,1,0,0,0,0,1,1,1,1,0,0,0,0),
(0,0,0,0,1,1,1,1,0,0,0,0,1,1,1,1),
(1,0,1,0,1,0,1,0,1,0,1,0,1,0,1,0),
(0,1,0,1,0,1,0,1,0,1,0,1,0,1,0,1),
(1,0,1,0,0,1,0,1,1,0,1,0,0,1,0,1),
(0,1,0,1,1,0,1,0,0,1,0,1,1,0,1,0)
And these are the resulting secret images after the share images are stacked:

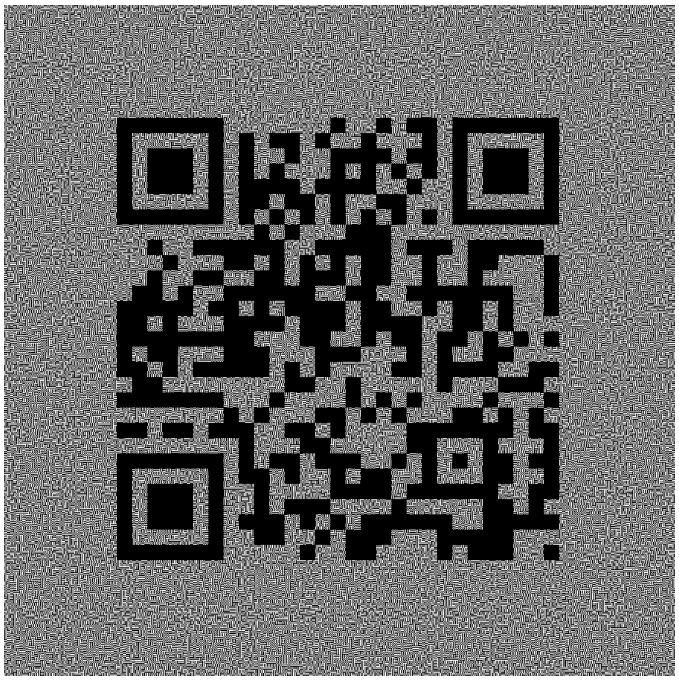

Figure 40 QR Code 2: Mixed, 4x4 Matrix

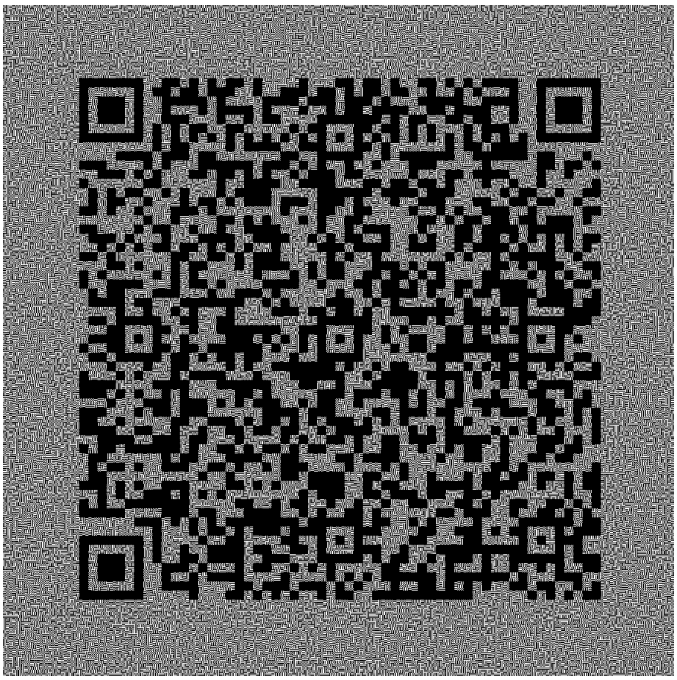

Figure 41 QR Code 3: Mixed, 4x4 Matrix

For all 12 QR codes, the resulting secret image can be successfully scanned and read by the QR code scanner. The background of the 4x4 matrix subpixel image is clearly smoother than the 2x2 and 3x3 subpixel image. The checkered pattern's background is so smooth the human eye perceives it as a flat gray background and almost cannot detect any noise in it.

IV. CONCLUSION

The pixel processing of creation of the share images results in a slightly different background of the secret image, but nonetheless it doesn't affect the performances of the QR code and it can still perform well within various configurations. It is suggested that the usage of larger subpixel matrix is better because it creates a smoother background thus helping the scanner application in detecting smaller squares in more complex QR codes.

REFERENCES

[1] Cao, X., Feng, L., Cao, P., & Hu, J. (2016). Secure QR Code Scheme Based on Visual Cryptography. Advances in Intelligent Systems Research, 433-436.