Readability of invisible quick response (QR) codes printed on valuable paper prints as security feature

Mahmoud Farouk El Feky
Assistant Professor, Printing, Publishing and Packaging Department,
Faculty of Applied Arts – Helwan University, Egypt, drmahmoudelfeky@gmail.com

Abstract:
Counterfeiting of security documents such as banknotes, checks, certificates, travel documents etc. is becoming now more than ever a serious problem, Various security features have already been introduced in the past to protect authentication or valuable prints from counterfeiting. And some of the already used anti-counterfeit and security features are special paper, special inks, watermarks, microprinting, security threads, holograms, etc. Though, there is still an urgent need to produce ingenious security features which considerably have to be cost-effective for the produced documents. So, this study aims to secure the most types used as a substrate for security prints with a new security feature that is difficult to counterfeit, an invisible quick response (QR) code, which can be printed with different capacities on these types of paper used in authentic documents, and can be read easily by smartphone cameras under special light sours, this could make these authentic documents difficult to be tamper. After experimental work study, the results have shown that QR code versions that encoded with low capacity of data, results in big modules (squares) in QR code structure, they can be read easily in most of paper types. Contrariwise, QR code versions that encoded with high capacity of data, results in small modules (squares) in QR code structure, they cannot be read easily in most of paper types, and in other types of paper, they never read, neither from all angles, nor by any types of smartphones. On the other hand, we have to take in consideration, the other parameters that are affecting on QR codes readability, like paper roughness, paper texture, paper color, the contrast between paper color and the invisible ink when lighted under the UV light source.

Keywords:
Forgery and counterfeiting, Valuable paper prints, Security features, Quick response (QR) code, invisible QR code, QR code capacities

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Introduction

Counterfeiting is a way of copying documents to make a fake look as genuine as possible. This should not be confused with forgery, which is making alterations to a genuine document. (Corbin Nakamura, 2010)

Counterfeiting of valuable prints is becoming now more than ever a serious problem, especially with the availability of high quality and low priced color print machines. So various security features have already been introduced to protect authentication or valuable prints from counterfeiting. In recent days and in an overgrowing market, the industry of security printing is striving for inventing new ideas of security features with less coasts. Some of these features are seen by the naked eye and are intended for public, while other features only the competent authorities can recognize by specified devices.

And some of the already used anti-counterfeit and security features like special paper, special inks, watermarks, microprinting, security threads, holograms, etc. Though, there is still an urgent need to produce ingenious security features which considerably have to be cost-effective for the produced documents.

In response to this need, the research *hypothesis* is to print an invisible quick response (QR) code as a new security feature that can be printed easily and with different capacities on some types of paper used in valuable prints, which makes them difficult for counterfeiters and forgers to imitate and tamper.

Originality/ value:

As the movement of using QR codes in securing valuable prints field, is still in its infancy, this paper serves to be one of the first comprehensive papers to fully delineate (a) the types of paper that can be secured by the invisible quick response (QR) code, (b) which types of QR codes that differ in capacities can be used as a security feature.

Literature Review:

What is QR code?

QR code is a two-dimensional code, it is widely useful in most of applications (Aryachandran S. and Jyothi R. L., 2014) for encoding of information in the form of URL, contact information, link to videos or photos, plain text and much more, (Sangeeta Singh, 2016). These different types of data exemplified in binary, numeric, alphanumeric, Kanji and control codes, and can be decoded quickly even if the code is partially damaged or dirty.

A QR code symbol can store up to 7,089 characters of information in both horizontal and vertical directions. And can read them from any direction. This is due to the presence of the finder patterns at three corners of the code that helps to define the code.

QR Codes are made of multiple rows and columns. The combination of these rows and columns makes a grid of modules (squares). There are 40 preset sizes that you must select from. These are referred to as versions. (Version 1) QR Codes will have 21 rows and 21 columns. Each version thereafter increases by 4 rows and 4 columns. The largest version is (Version 40) which has 177 rows and 177 columns and results in the 31,329 needed to encode the 3kb of data. (http://qrcode.meetheed.com/question7.php)

As the amount of data increases, more squares are required to compose QR Code, getting in bigger QR Codes

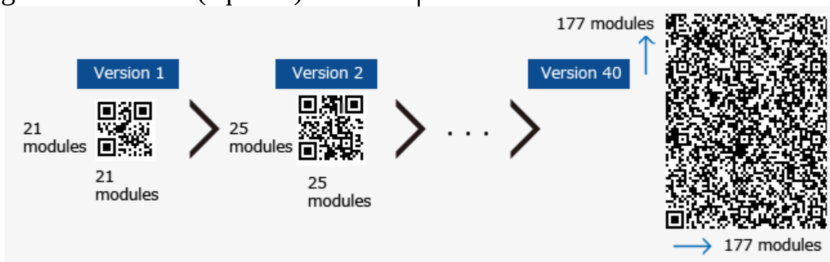

Figure 1: Illustrates the QR Code versions structure

Also the size of a QR Code is important for it to scan well. You know that QR Codes are commonly scanned using a smartphone. (https://scanova.io/blog/blog/2015/02/20/qr-code-minimum-size/) Any Smartphone equipped with a camera can read the content of QR code directly. (Shruti Ahuja, 2014),

You have to be sure that your QR Code size is big enough to be read by most of the smartphones cameras. Its size should be at least 2.5 x 2.5 cm. In general, to calculate the right QR Code size, you have to keep in mind a few things:

- The ratio of the scanning distance to the size of the QR Code should be close to 10:1. i.e. QR code minimum size=Scanning Distance/ 10
- The data is encoded across QR Code rows and columns. If you increase the data, the number of rows and columns also increase. As a result, the readability decreases. To ensure higher readability of QR Codes, you have to apply this rule: QR code minimum size= (Scanning Distance X No. of Rows and Columns)/250
- Adding colored illustrations or photos to QR code help in attracting the maximum number of scans, instead of using boring plain black and white QR codes. So, many companies customize their QR Codes by adding their logos and colors to it.
- Color contrast between QR code and its background must be high enough.
- QR code format must be vector, like SVG, EPS, or PDF formats. To be scaled easily without damage.
- Finally, QR Code should be surrounded by convenient quite zone, that be equal to about four data modules. This helps in reading the QR code properly.

This paper supposes that printing an invisible QR code with different capacities on some types of paper used in authentic documents, works as a new security feature that can be read easily by smartphone cameras under special light sours, this could make these authentic documents difficult to be tamper.

Security Printing

The main goal of security printing is to prevent forgery or counterfeiting. It is responsible for protecting sensitive paper documents such as banknotes, cheques, passports, certificates, stamps from counterfeiting. Alongside these examples, vouchers, birth and death certifications, and brand protection labels. (Aleksandra Kaminska, 2019),

Some of the already used anti-counterfeit and authentication features are special paper, special inks, watermarks, micro-letters, security threads, holograms, etc. (Aryachandran S. and Jyothi R. L., 2014) Though, there is still an urgent need to produce ingenious security features which considerably have to be cost-effective for the produced documents. Printing a valuable document using non-standard inks rather than the standard CMYK inks provides an additional level of security. (Isaac Amidror, 2002) Using special inks that differ in gamut from the standard process colors (CMYK) inks, can guarantee that the colors of counterfeited document will quite deviate from the original colors of an authentic document printed by regular color print machines. A wide variety of security inks can be used in paper documents. In addition, the printer can also use overprint varnishes and lamination layers to make counterfeiting more difficult. Many security printing inks depend on the absorption of UV radiation and its re emission as visible light. Therefore, to work fairly, many security designs and features must be printed on uncoated paper. On other media they will only work if there are no UV brighteners in the substrates. (Iskren et al, 2018) invisible Inks like UV fluorescent ink are special because they cannot be seen by the naked eye under normal lighting sources. It requires UV light to be visible to the naked eye. This ink offers a covert security feature by not being detectable without the proper short-wave, or long-wave UV illumination. (Corbin, 2010), Fluorescent dyes are dyes which fluoresce under UV light or other unusual lighting. These show up as words, patterns or pictures and may be visible or invisible under normal lighting. (T. Bozhkova et al, 2017)

Objectives

This study aims to secure some types of paper used in valuable prints with a new security feature that is difficult to counterfeit, an invisible quick response (QR) code, which can be printed with different capacities on these types of paper used in authentic documents, and can be read easily by smartphone cameras under special light sours, this could make these authentic documents difficult to be tamper.

Methodology

In order to achieve the research objectives, an experimental study is conducted as following:

Materials and procedures:

1- A test form of 13 invisible QR codes patches as shown in (***figure 2***) were generated by Adobe InDesign CC 2020 software, encoded by some information about the author. These patches were selected to test the effect of using some factors on readability of them after printing on different types of paper used as main materials for the valuable formalized documents, as following:

- Patches were selected in versions of (from Version 1 to Version 10, Version 20, Version 30 and Version 40)
- These versions differ in data encoded and subsequently in modules number and size.
- It was taking into consideration, preparing all patches by using a vector app (Adobe InDesign) and then exporting them in a vector format like (EPS) to ensure getting the best quality when printing.
- All patches were prepared to be printed in a size from (2cmx2cm) to (2.5cmx2.5cm) according to version.

2- The 13 invisible QR codes were printed by (BUSKRO INKJET CONTROLLER) machine as following:

- All patches were prepared to be printed with invisible ink (FlexPrint UV Invisible)
- All patches were prepared to be printed on different types of paper like (Secured, Calque, Fabriano, Martele, Coche, Fiber, Canson, Crystal and Kraft), as the most types used as a substrate for security prints.

3- The 13 invisible QR codes were lighted under UV light source (HANDHELD BLACKLIGHT). as shown in (***figure 3***)

4- Three different smart phones with (Android, Windows, and iPhone operating Systems) with three different decoding software (QR Code Reader, QR Droid Scanner, and QR Quick Scanner) were used to read all printed patches, to assure the scan reliability, (Jason S., 2012) says "It's always a good idea to test your codes for scan reliability on a range of QR code readers, and on multiple device types".

5- A table was structured to outline the key results of QR code reading, (see table 1).

6- A table was structured to outline the QR code reading results, (see table 2).

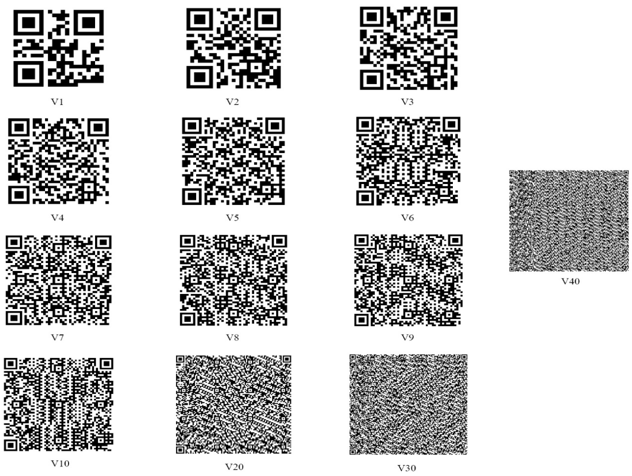

Figure 2: Illustrates the test form of 13 invisible QR codes patches

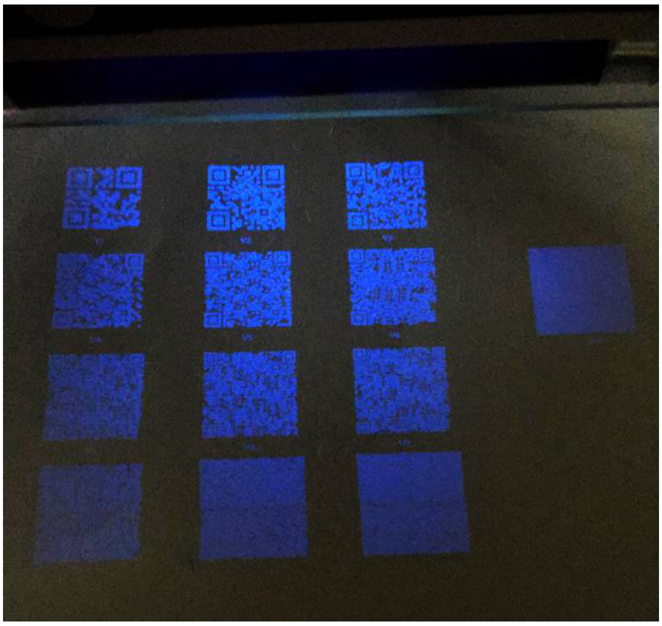

Figure 3: Illustrates the printed invisible QR codes were lighted under UV light source (HANDHELD BLACKLIGHT).

Results:

There are three different results, and the following table (Table 1) outlines the Key results for the research experimental procedures:

Table 1: outlines Table Key results**:**		
Readable QR codes from the first time	Difficult Readable QR codes	Unreadable QR codes
✓	D	×

Table 2: outlines the reading results of patches from 1 to 13 were printed on some types of paper used in valuable prints

Paper Type	**Patch Version / QR codes Readability**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**20**	**30**	**40**
Secured	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×
Calque	✓	✓	✓	✓	×	×	×	×	×	×	×	×	×
Fabriano	✓	✓	✓	✓	✓	✓	**D**	×	×	×	×	×	×
Martele	✓	✓	✓	✓	✓	✓	✓	✓	**D**	×	×	×	×
Coche	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	×
Fiber	✓	✓	✓	✓	✓	×	×	×	×	×	×	×	×
Canson	×	×	×	×	×	×	×	×	×	×	×	×	×
Crystal	×	×	×	×	×	×	×	×	×	×	×	×	×
Kraft	×	×	×	×	×	×	×	×	×	×	×	×	×
Striped	×	×	×	×	×	×	×	×	×	×	×	×	×

Discussion:

- **Firstly: For the QR code versions (V20, V30 and V40):**

They were not read definitively, as shown in table 2, from any type of paper, from all angles, and by the three types of smartphones, because these three QR code versions particularly, built from very small modules (squares) according to their capacities (High capacity QR code versions), compared to the rest versions.

- **Secondly: For the QR code versions from (V1 to V10):**

They were varied in readability, as shown in table

2, as following:

1- The QR code versions from V1 to V4 which are built almost from big modules (squares), were read easily from the first time in most of paper types like Secured, Calque, Fabriano, Martele, Coche and Fiber paper, and were not read definitively in the rest types of paper, here we have to take in consideration, the other parameters that are affecting on QR codes readability, like paper roughness, paper texture, paper color, the contrast between paper color and the invisible ink when lighted under the UV light source.
2- The QR code versions from V5 to V10 which are built almost from medium modules (squares), were varied in readability among the three cases [Readable QR codes from the first time (✓), Difficult Readable QR codes (**D**) and finally, Unreadable QR codes (✕)], also in most of paper types like Secured, Calque, Fabriano, Martele, Coche and Fiber paper, and were not read definitively in the rest types of paper, because of the same parameters that are affecting on QR codes readability, like paper roughness, paper texture, paper color, the contrast between paper color and the invisible ink when lighted under the UV light source.

Conclusion

As a result of the investigation, the following conclusions have been drawn:

- QR code versions that encoded with low capacity of data, results in big modules (squares) in QR code structure, they can be read easily in most of paper types used as a substrate for security prints. Contrariwise, QR code versions that encoded with high capacity of data, results in small modules (squares) in QR code structure, they cannot be read easily in most of paper types used as a substrate for security prints, and in other types of paper, they never read, neither from all angles, nor by any types of smartphones.
- We have to take in consideration, the other parameters that are affecting on QR codes readability, like paper roughness, paper texture, paper color, the contrast between paper color and the invisible ink when lighted under the UV light source.

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