Rich QR Code for Multimedia Management Applications

Iuliia Tkachenko[1,2](✉), William Puech[1], Olivier Strauss[1], Christophe Destruel[2], Jean-Marc Gaudin[2], and Christian Guichard[2]

[1] LIRMM, UMR CNRS 5506, University of Montpellier, Montpellier, France
[2] Authentication Industries, Montpellier, France
iuliia.tkachenko@lirmm.fr

Abstract. The Quick Response (QR) code is the most popular graphical code in the world today. These codes are used for storage of information, but they have a limited storage capacity. In this paper, we present a two level QR (2LQR) code, which stores information on two levels. The first (public) level is accessible to everyone and can be read by any classical QR code reader. The second (supplementary) level is readable only by a selected group of users, which have a specific reader application. This code increases storage capacity of standard QR code. We use specific textured patterns for construction of a second level. We also suggest a blind pattern recognition method, which is based on maximization of correlation values.

Keywords: QR code · Two level stored information · Pattern recognition · Print-and-scan process · Multimedia management application

1 Introduction

Today, Quick Response (QR) codes are used in many applications, reaching more and more users: from consumers who look for information (reference to an URL from a smartphone) to professionals who think about quality of its product information (information storage - serial number, date - for market control and quality management). One of the popular application of QR codes is multimedia management [12]. This interest is due to several interesting characteristics of QR code: small size, high coding and error correction capacities, robustness against geometrical distortion, easy generation and reading process. Nevertheless, these codes have a limited storage capacity. Moreover, the information that is stored in these codes, is accessible to everyone who has the standard reading QR application. So, in standard QR codes we can only store public information.

In this paper we suggest a two level QR (2LQR) code, that can be used, for example, for automatic tracing and tracking of printed documents (bills, tax forms, reports). This code allows to split information into public (first level of information storage), which is accessible to all users, who have the standard QR code reading application, and supplementary information (second level of

V. Murino and E. Puppo (Eds.): ICIAP 2015, Part II, LNCS 9280, pp. 383–393, 2015.
DOI: 10.1007/978-3-319-23234-8_36

information storage), which is useful only for administrative purposes. This supplementary information is accessible only to authorized users, who have a specific reading application, that permits to read and decode this information. Thus, this 2LQR code add new capacities to standard QR code:
1. Supplementary reading level, which does not disrupt the standard QR code reading process.
2. Increasing storage capacity of initial QR code.

The standard QR code used as first level of our 2LQR code stays fully functional: it can be read by all standard application, without any restriction; all standard features stays optimal, for example, the error tolerance of the QR code stays maximal; it is not perturbed by the second level information which is not present at this first level. Thus, our 2LQR code ensure privacy of data stored in the second level not only by applying a classic numeric ciphering, but also by a physical separation, between levels and reader application abilities.

The second level of information storage is performed by using specific textured patterns, which are distinguished one from another after printing and scanning processes.

The paper is organized as follows. Section 2 introduces the QR code features and the existing rich graphical codes. The proposed two level QR code as well as the proposed recognition methods are presented in Section 3. Section 4 looks at the experimental results and we conclude in Section 5.

2 Related Work

Graphical codes are very popular now, because of easy generation and fast reading process. Standard graphical codes are black-and-white (or with two contrasting colors) as EAN-13 barcodes [1], QR code [3], DataMatrix [2]. But today, a lot of research projects and researchers suggest improvements to these graphical codes by using colors or time. These improved graphical codes can be named as *rich graphical codes*. In this paper we propose a new type of rich QR code, thus in Section 2.1 we present the main characteristics and structure of standard QR code and the existing rich QR codes are discussed in Section 2.2.

2.1 QR Code Features

The QR code was invented for the Japanese automotive industry by Denso Wave[1] corporation in 1994. The important characteristics of this code are small printout size and high speed reading process. The certification of the QR code was performed by International Organization of Standardization (ISO). That is why, all specifications can be found in [3].

A QR code encodes the information in binary form. Each information bit is represented by a black or white module. The Reed-Solomon error correction code (RS-ECC) [10] is used for data encoding. Thus, one of 4 error correction levels has to be chosen during QR code generation. The lowest level can restore nearly 7% of damaged information, the highest level can restore nearly 30%. Today,

[1] http://www.qrcode.com/en/index.html

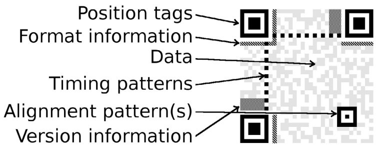

Fig. 1. Specific QR code structure consists of position patterns, alignment patterns, timing patterns, format information and version information patterns.

there are 40 QR code versions depending on storage capacity. The maximum number of information bis, that can be stored in standard QR code, is equal to 7089.

The QR code has a specific structure for geometrical correction and high speed decoding. All specific patterns are illustrated in Fig. 1.

2.2 Rich Graphical Codes

In order to improve the QR code properties, the rich QR codes have recently been introduced. These rich QR codes aim to add visual significance, to personalize the stored information and to increase the storage capacities. The most simple rich QR code is the design QR code[2], where we change the colors, shape of modules or add an image into the QR code. The target of these codes is to improve the aesthetic view of QR codes. But this kind of code reduces the error correction capacity of standard QR codes. A rich QR code, which adds the significance without losing error correction capacity, was introduced in [4]. The authors proposed a novel method of blending a color image into the QR code, which modifies the QR code source pixels so that the white (rsp. black) module pixels are transformed from white (rsp. black) to any RGB values and whose luminance value is considered as white (rsp. black) pixel by QR code binarization method. The HCC2D code [8] is a rich QR code which significantly increases the storage capacity of standard QR codes. The authors increased the density and storage capacity of standard QR code by replacing binary colored modules by RGB colored modules. The HCC2D code encodes information using 4, 8 or 16 module colors. This code inherits all the strong properties of standard QR codes, but it is not readable by a standard QR code reading application and needs to be printed using a color printer. One of the application scenarios for HCC2D code is facial biometrics [9]. The QR code steganography aims to embed a secret message into a QR code [6,7]. The message insertion is performed by using Reed-Solomon error correction code (RS-ECC) capacity of the QR code, that does not disturb the reading process of the standard QR code.

The main difference between the 2LQR code and all existing techniques is focused on the 2 level functionality. Most of existing techniques can be

[2] For example: https://www.unitag.io/qrcode

considered as a new code format (HCC2D). On the other hand, several codes add a supplementary messages (visual or hidden) to a standard QR code [4,6,7]. This kind of code uses the RS-ECC to add this supplementary information that implies, by construction, a very constrained storage. The 2LQR code do not have this very strong limit and do not alter the standard QR code reading. This short discussion shows the rich graphical codes popularity, research interest and variety of application scenarios.

3 Rich QR Code with Two Stored Levels

In this section we aim to present a rich QR code with two stored levels. In Section 3.1, we explain the generation steps of 2LQR code, and the recognition method is introduced in Section 3.2.

3.1 Two Level QR (2LQR) Code Generation

As it was mentioned in Section 1, the proposed 2LQR code have all the strong characteristics of the standard QR code [3] such as: small code size, high encoding capacity, high density, error correction capacity, easy code construction and quick reading process. In addition, the 2LQR code has two information levels. The first level contains public information and can be read by any QR code application, i.e. iOS, Android and scanner applications. That is why the proposed 2LQR code satisfies all standard QR code features. The second level contains supplementary information and is realized by replacing black modules in QR code with two specific textured patterns. The combination of these textured patterns allows to encode and afterwards, to reconstruct the supplementary information. Fig. 2 shows the difference between a standard QR code and the proposed 2LQR code. To increase robustness of this second level information, it is encoded using a binary error correction code. As illustrated in Fig. 3, the 2LQR code generation consists of the following steps: 1) Generation of standard QR code with a public information M_{pub}; 2) Generation of codeword C_{sup} with a supplementary information M_{sup}; 3) Selection of textured patterns P_1, P_2; 4) Replacement of black modules in standard QR code by textured patterns P_1, P_2, respecting codeword C_{sup}.

Standard QR Code Generation: in this step we store a public information M_{pub} in a standard QR code using the method described in ISO standard [3]. The QR code generation algorithm includes the following steps. Firstly, the input

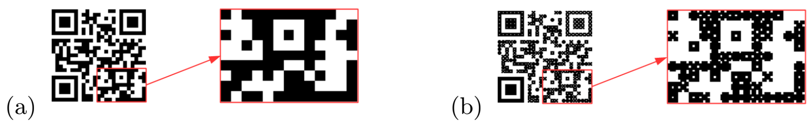

Fig. 2. Comparison between: a) Standard QR code, b) Proposed 2LQR code.

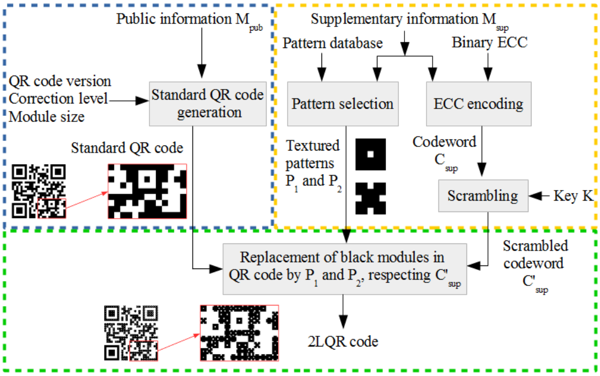

Fig. 3. Overview of the proposed 2LQR code generation steps.

data is encoded with the RS-ECC [10] with error setting correction level. The bit streams are formed and divided into codewords, which have an 8 bit length. The codewords form the blocks, in which the error correction codewords have been added. Then, the mask pattern is used for codewords masking. The codewords are placed from the right-bottom corner to the left-top corner in a zigzag pattern. A more complex codeword placement is used for the highest QR code versions due to the alignment pattern presence and interleaved error-correction blocks. At the last step, the function patterns are placed into the QR code.

Generation of Codeword C_{sup}: we encode the supplementary information M_{sup} using a binary error correction code (ECC) such as Golay code, BCH code or Reed-Solomon code [10]. The classical encoding function $\mathbb{C} : \mathbb{F}^k \to \mathbb{F}^n$ for linear codes is defined as follows. Let G be the $k \times n$ generator matrix of linear ECC with elements in $\mathbb{F}$ and $M_{sup} = (m^1_{sup}, ..., m^k_{sup}) \in \mathbb{F}^k$. Then, the codeword is calculated as $C_{sup} = M_{sup} \cdot G$. After, that we apply a scrambling operation with key K in order to mix codewords and add the supplementary protection to specific information. Thus, we obtain the scrambled codeword C'_{sup}.

Selection of Textured Patterns P_1, P_2: the textured patterns are the squared images $P_i, i = 1, 2$ of size $p \times p$ pixels. This kind of patterns was used in textured image generation [11]. These patterns are chosen from a pattern database, which contains $N, N >> 2$ patterns, and have the particular properties: 1) Images are binary, 2) The number (density) of black pixels is constant and equal to d, 3) The spectra are related among them. These criteria are important: any variation of density in pattern modules will introduce a distortion in the correlation computation during the detection step. The classification of patterns could be skewed and the result could not be validated.

As the proposed recognition method is based on maximization of correlation values, the textured patterns have to respect two conditions [11]: 1) Each pattern has to be better correlated with its Print-and-Scan (P&S) degraded version than with all other P&S degraded pattern versions; 2) The P&S degraded version of each pattern has to be better correlated with its original pattern than with all other original patterns. Only the textured patterns that respect these conditions can be combined among them and can be recognized after P&S process, thus these patterns can be used for insertion of supplementary information M_{sup} into 2LQR code. Let patterns P_1, P_2 be chosen with respect to all described conditions and be used for supplementary information insertion.

Replacement of Black Modules: the black modules in standard QR codes are replaced by textured patterns P_1, P_2, respecting codeword C'_{sup}. We start to insert codeword C'_{sup} from the right-bottom corner of the standard QR code. Note, that we do not insert the encoded information into the modules in QR code position patterns. These patterns are reserved for the storage of used textured pattern templates.

3.2 Recognition Methods

The QR code reproduction implies the printing process and the scanning process. The Print-and-Scan (P&S) process is a difficult process, which modifies the output image. These visible and invisible image modifications can be introduced by sampling inherent to the P&S process, inhomogeneous lighting conditions, ink dispersion, varying speed of the scanning device [5]. The modifications inserted by the printer are not separable from modifications added by the scanning process, that is why the distortions belong to each other [13]. Let S_i be the P&S degraded version of textured pattern P_i. The Fig. 4 illustrates all steps of the 2LQR code reading process. First of all, we apply the standard QR code pre-processing into the P&S 2LQR. The standard process [3] of position pattern localization is applied in order to determine the position coordinates. Then, the standard re-sampling method using bilinear interpolation is applied. As an output we have 2LQR code with correct orientation and original code size.

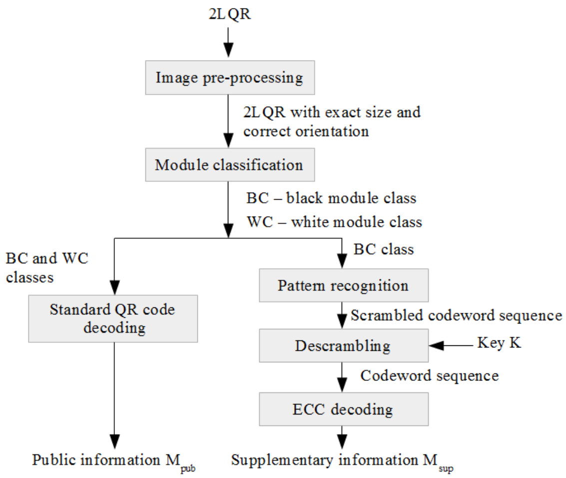

Fig. 4. 2LQR code reading process.

Then the module classification step is performed by any binarization method, either global threshold methods (standard ISO binarization method or Otsu's binarization method) or local threshold methods. In this paper, we set a global threshold equal to mean value of whole image. When the modules are classified in two (white and black) module classes, we can decode the public information M_{pub} using standard QR code decoding algorithm and use the black module class for pattern recognition and supplementary information decoding.

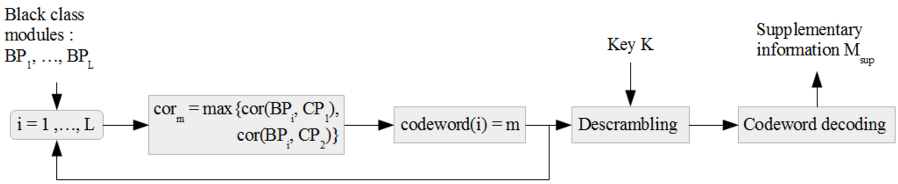

Fig. 5. Supplementary information decoding algorithm.

The blind pattern recognition, illustrated in Fig. 5, does not need any particular information in input. We define this method for combination of two patterns P_1, P_2. During the 2LQR generation, we replaced all black modules of left-top position pattern and right-top position pattern by textured patterns P_1 and P_2, respectively. These patterns are used for generation of characterization models of original textured patterns P_1 and P_2. Each position pattern consists of $t = 33$ black modules (for any QR code version). We calculate characterization models as:

- the *mean images* obtained by averaging the t P&S textured patterns : $CP_l = \frac{1}{t}\sum_{\tau=1}^{t} S_l^{\tau}, l = 1, 2$;
- the *median image*: $CP_l = median(S_l^1 \cdots S_l^t), l = 1, 2$. During the recognition step, we use the Pearson correlation between a pattern P_i and a pattern S_i, which is defined by:

$$cor(P_i, S_i) = \frac{\sum_r \sum_c (P_i^*(r,c))(S_i^*(r,c))}{\sqrt{\sum_r \sum_c (P_i^*(r,c))^2}\sqrt{\sum_r \sum_c (S_i^*(r,c))^2}}, \tag{1}$$

where $P_i^*(r,c)$ (rsp. $S_i^*(r,c)$) are the central values of P_i (rsp. S_i) defined by $P_i^*(r,c) = P_i(r,c) - \mu_{P_i}$ (rsp. $S_i^*(r,c) = S_i(r,c) - \mu_{S_i}$) with $\mu_{P_i} = \frac{1}{k}\sum_r \sum_c P_i(r,c)$ (rsp. $\mu_{S_i} = \frac{1}{k}\sum_r \sum_c S_i(r,c)$).

Let $BP_1, ..., BP_L$ be black information modules from the 2LQR code. For each module BP_i, we calculate correlation value with CP_1 and CP_2 (values cor_1 and cor_2 respectively). The maximal correlation value corresponds to the type of inserted pattern. That is why, if $cor_1 > cor_2$, the $codeword(i) = 1$, else $codeword(i) = 0$. When the $codeword$ is determined, we apply, firstly, the descrambling operation with key K, and, secondly, the ECC decoding algorithm in order to extract the supplementary information M_{sup}.

4 Experimental Results

In this section, we illustrate both the generation steps of the proposed 2LQR code and the recognition algorithm. The application scenario is as follows. We store information in the public level: Surname, Name, Date of Birth and Place of Birth. In the second level, we encode the security number of this person. We use the version V2 of QR code using Low error correction level. The version V2 of QR code has 25×25 module size and can store 272 bits of the message in the low error correction level. For supplementary information encoding, we use the binary Golay code $[23, 12, 7]$. It means, that the codeword length is 23 bits, where the length of the encoded information is 12 bits and 11 bits are used for error correction. In QR code version V2, we have 216 black modules (we do not take into account the black modules used in position pattern construction), thus we can store about 216 bits of encoded information (including error correction bits) in the second level of the 2LQR code. Therefore, we can store 108 bits of a supplementary information in second level of 2LQR code version V2. In Table 1, we determine the storage capacities of both standard QR code and 2LQR code.

Table 1. Storage capacity information of standard QR code and 2LQR code.

	Standard QR code V2 Low	2LQR code V2 $[23, 12, 7]$ code
Modules	625	312
Encoded bits	324	216
Message bits	272	108

4.1 Generation of 2LQR Code

We generate the standard QR code of version V2 with the public M_{pub} information: "John Doe - 13/05/1958 - New York" by using any QR code application, see Fig. 6. Then, we define the supplementary information M_{sup} with a length of 108 bits and the used textured patterns. As we decide to use the binary Golay code we create the codeword C_{sup} of 207 bits, where we will store 108 bits of the

(a) (b)

Fig. 6. The example of a) Standard QR code with public information M_{pub}, b) Standard QR code of real size defined at 600 dpi.


(a) (b)

Fig. 7. The used textured patterns: a) Pattern 1, b) Pattern 2.

supplementary information. The last 9 accessible bits were defined randomly. Then, after scrambling, we obtain the codeword C'_{sup}.

We choose two textured patterns P_1 and P_2 (see Fig. 7.a - Fig. 7.b). These patterns have a size of 12×12 pixels and respect 3 mentioned properties, the number of black pixels is equal to $d = 72$.

We encode the second level of 2LQR code placing these patterns with respect to codeword C'_{sup}, starting from right-bottom corner of the QR code. We replace black modules by textured patterns P_1 and P_2 in the top-left and top-right position patterns, respectively. The example of 2LQR code is illustrated in Fig. 8. We set the size of 2LQR code equal to 1.2×1.2 cm^2. The examples of 2LQR code in real size is illustrated in Fig. 8.c. The standard QR code, as well as, the public level of 2LQR code are readable by standard smartphone application in Fig. 6.b and Fig. 8.c.

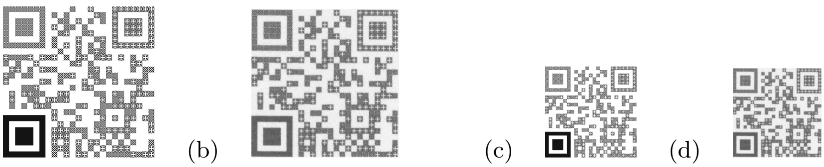
(a) (b) (c) (d)

Fig. 8. The example of a) 2LQR code with both public M_{pub} and supplementary M_{sup} information, b) P&S 2LQR with two levels of stored information c) 2LQR code of real size defined at 600 dpi and d) P&S 2LQR code of real size defined at 600 dpi.

4.2 Message Extraction

We printed the same 2LQR code 30 times in 600 dpi using Brother HL-4150 printer. Then, we scanned each printed 2LQR code in 600 dpi using Canon LIDE 210 scanner. After several experiments with P&S samples, we have concluded that the database of 30 samples is enough to perform the correct statistical tests due to random impact of P&S process. An example of P&S 2LQR code is illustrated in Fig. 8.b and Fig. 8.c. We can note the image blur and changes of colors in comparison with original 2LQR code Fig. 8.a. In spite of these changes the public level is readable by standard QR code applications. For each P&S 2LQR, we apply the blind detection method both with mean and median characterization patterns. We present the detection results in Table 2. The error probability of pattern detection using proposed blind method is 1.64% with mean characterization patterns and 1.23% with median characterization patterns.

Table 2. Pattern detection results after P&S process.

	Mean	Median
% of P_1 detected as P_2	0.95%	1.33%
% of P_2 detected as P_1	2.28%	1.14%
Error probability of pattern detection	1.64%	1.23%

Table 3. Error probability of incorrect message decoding after error correction algorithm.

Error probability of incorrect	Mean	Median
bit decoding after ECC	0.65%	0%

After the detection step, we apply the descrambling, error correction and decoding algorithms. In the end, we find the encoded supplementary information M_{sup}. Sometimes, due to bad pattern recognition results, the supplementary message was decoded incorrectly. The error probabilities of incorrect bit decoding are presented in Table 3. We had some errors in message decoding process after pattern detection using mean characterization patterns. At the same time, we did not have errors during message decoding process after pattern detection using median characterization patterns.

5 Conclusion

In this paper we propose a new efficient rich code called two level QR (2LQR) code, which can be used for automatic tracing and tracking of printed documents. This rich QR code has two levels. The first level can be read by any QR code reading application. On the contrary, the second level needs a specific application. The second level is created by using specific binary textured patterns, which are distinguishable from one another after P&S process and are considered as black modules by standard QR code reading applications. Thus, the second level does not affect at all the reading process of first level. The experimental results were performed for QR code version V2, the supplementary information has a length of 108 bits and was encoded using binary Golay $[23, 12, 7]$ error correction code. The pattern detection was performed for mean characterization models and median characterization models. The probability of correct bit decoding after ECC is equal to 99.35% after pattern detection using mean characterization models, and to 100% after pattern detection using median patterns. In future we plan to study the capacities of 2LQR code, depending on both QR version and pattern size, as well as, to propose other pattern recognition algorithms, that will be less sensitive to P&S impact.

References

1. 15420:2009, I.: Information technology - Automatic identification and data capture techniques - EAN/UPC bar code symbology specification (2009)
2. 16022:2006, I.: Information technology - Automatic identification and data capture techniques - Data Matrix bar code symbology specification (2006)
3. 18004:2000, I.: Information technology - Automatic identification and data capture techniques - Bar code symbology - QR Code (2000)
4. Baharav, Z., Kakarala, R.: Visually significant QR codes: Image blending and statistical analysis. In: IEEE International Conference on Multimedia and Expo, ICME 2013, July 15–19, pp. 1–6, San Jose, California, USA (2013)
5. Baras, C., Cayre, F.: 2D bar-codes for authentication: A security approach. In: The 20th European Signal Processing Conference, EUSIPCO 2012, August 27–31, pp. 1760–1766. Bucharest, Romania (2012)
6. Bui, T.V., Vu, N.K., Nguyen, T.T., Echizen, I., Nguyen, T.D.: Robust message hiding for QR code. In: 2014 Tenth International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), pp. 520–523. IEEE (2014)
7. Lin, P.Y., Chen, Y.H., Lu, E.J.L., Chen, P.J.: Secret hiding mechanism using QR barcode. In: 2013 International Conference on Signal-Image Technology & Internet-Based Systems (SITIS), pp. 22–25. IEEE (2013)
8. Querini, M., Grillo, A., Lentini, A., Italiano, G.F.: 2D color barcodes for mobile phones. IJCSA **8**(1), 136–155 (2011)
9. Querini, M., Italiano, G.F.: Facial biometrics for 2D barcodes. In: IEEE Federated Conference on Computer Science and Information Systems, FedCSIS 2012, September 9–12, pp. 755–762, Wroclaw, Poland (2012)
10. Sklar, B.: Digital communications, vol. 2. Prentice Hall, NJ (2001)
11. Tkachenko, I., Puech, W., Strauss, O., Gaudin, J.M., Destruel, C., Guichard, C.: Fighting against forged documents by using textured image. In: The 22nd European Signal Processing Conference, EUSIPCO 2014, September 1–5, pp. 790–794, Lisbon, Portugal (2014)
12. Villán, R., Voloshynovskiy, S., Koval, O., Pun, T.: Multilevel 2d bar codes: Towards high capacity storage modules for multimedia security and management. IEEE Transactions on Information Forensics and Security **1**(4), 405–420 (2006)
13. Yu, L., Niu, X., Sun, S.: Print-and-scan model and the watermarking countermeasure. In: Image and Vision Computing, vol. 23, pp. 807–814. Elsevier (2005)