2D Codes - Light Fastness and Readability

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Abstract

2D (two dimensional) barcodes have data encoded in both horizontal and vertical directions. They contain more information than 1D barcodes with data encoded in horizontal direction only. Conventional 1D barcodes have a single row of bars that get wider as more data is encoded. In 2D barcodes hundreds of characters can be embedded in a single barcode.

The main advantage of using 2D barcodes is that a large amount of easily and accurately read data could be placed on the barcode without increasing the size of the label significantly. In addition to holding large amounts of data, 2D barcodes require much less quiet zone (only one cell width around), which allows symbol location to be much closer to surrounding text and/or graphics. One of amazing aspects of 2D barcodes is their durability as compared to conventional barcodes. This is due in part to its excellent error checking and correction.

The goal of our research was focused on determination of the limited intensity between printing color and substrate, which could enable accurate code capturing and reading. Two standard 2D codes (differ in size and amount of encoded information) were printed separately with cyan, magenta, yellow and black color by using inkjet-printing technology. The color intensities of printed codes were in the range from 15 % (20, 25, 30, 50) to 100 % raster tone values. One half of the printed samples was exposed to light fastness test according to standard SIST ISO 12040. All samples exposed and not exposed were captured with 2D reader. At the end the limiting intensity for all samples were determined and evaluated by 2D reader and image analysis (ImageJ software).

Introduction

In 1934 J. T. Kermode et al published one of the very first patents that disclosed some of the basic bar code concepts. With that patent they have started arranging and restraining different types of products and that was a basic for further barcode concept. [1] Linear barcode encoding still enables quick and accurate data capturing encoded in codes. In spite of this linear barcodes are too big to be printed on small products and enable encoding only small amount of data. Based on this the early 1990s brought a development of two-dimensional codes that enable to encode data in horizontal and in vertical directions and consecutively encoding larger amount of data on smaller space. In 1992 [1] the first world`s public-domain two-dimensional matrix symbology was developed.

By today four of two-dimensional barcodes have been standardized and we can see them printed on different products independently or beside one-dimensional barcodes.

Two-dimensional barcode symbologies

In our research we have used two standard codes namely DataMatrix and QR (Quick Response) code. These codes are applied on different types of packaging, commercial tracking applications etc.

DataMatrix

Figure 1. *DataMatrix code [2].*

DataMatrix is a two-dimensional code that has a maximum theoretical density of 500 million characters per inch. The practical density is limited by the resolution of the printing and reading technology. It was developed to provide a large amount of information on a small space. Each DataMatrix code has two adjacent sides printed as solid bars and the other two adjacent sides are printed as a series of equally spaced square dots. Unique perimeter pattern helps the barcode scanner to determine the cell locations, symbol orientation and printing density. The cells are made up of square modules. [3]

QR code

Figure 2. *QR code [4].*

QR Code (Quick Response Code) is a two-dimensional matrix symbology that uses an array of square data cells and three fixed orientation targets. At its maximum size it can encode up to 7,089 numeric digits. [1] QR code is designed for rapid reading using CCD array cameras and image processing technology because of the layout of the finder pattern. [3]

Methods and materials

Generating and prepress of 2D codes

Samples with 2D codes were generated with free online [2, 4] 2D code generators. We generate DataMatrix (DM) and Quick Response (QR) code with URL address and both of codes with paragraph encoded. Prepress of codes was done by Adobe Photoshop software in four process inks; cyan (C), magenta (M), yellow (Y) and black (K). Each of those codes was than prepared in the range from 15 (20, 25, 30, 50) to 100 % raster tone value and printed on 230g/m^2 cardboard Reno de Medici (Reno de Medici, Italy) using inkjet HP Deskjet 5652 printer.

Capturing 2D codes with code reader

Codes were read using Symbol technologies DS 6607 reader at standard daylight. A chamber the judge II (Gretag Macbeth) was used to illuminate the samples at 45° angle. The results of 2D codes reading were divided in three classes: (1) quickly readable codes; (2) readable codes (3) not readable codes.

Light fastness

Samples were exposed to artificial light (Xe-light). Testing was performed using Xenotest Alpha (Atlas, USA) in accordance with ISO 12040 standard.

Table 1. Illumination conditions.

Radiation intensity	E = 42 W/m^2
Number of phase	1
Time of one phase	60 min
Chamber temperature	CHT = 35 °C
Black standard temperature	BST = 50 °C
Relative humidity	RH = 35 %
Manner of illumination	Turning mode
Filter	Xenochrom 320
Total time	72 h

Light fastness is dependent on printing material and chemical structure of printing ink. Next to that the thickness of printing ink (or printing pigment) also influences the light fastness, which is important especially for packaging materials, which are often exposed to sunlight.

After light fastness testing the lowest raster tone value for detecting code was determined again.

Analysing with ImageJ

Samples of 2D DM codes were scanned with scanner and analyzed with ImageJ [5] software. Image samples were converted to 8 bit images and the threshold for each sample was determined. We applied the same threshold for each image of the captured sample. Finally the comparison between threshold images and results of readability of codes made by barcode reader was made.

Results and discussion

2D barcode reading before illumination

Small DM and QR codes have encoded URL address and big codes alphanumerical paragraph. In table 2 we can see the best results were achieved with black printing ink where the contrast between barcode and printing material was the highest. The reader quickly reads the black DM printed codes at only 20 % of raster tone value. The worst results were obtained by yellow printed codes, which were almost unreadable. Only at 100% DM codes they became readable. Cyan DM codes printed in inkjet technique were fast readable at 25 %, QR codes on the other hand at 30 % raster tone value. Magenta DM codes were readable also at 30 %, QR codes were readable at 50 % raster tone value. Better results were achieved at DM codes that had better or the same readability than QR codes at the same printing ink. Similar observations were obtained for small codes that assure better reading conditions than large codes or codes with large amount of data encoded.

As we can see on figure 3 yellow printing ink is not suitable for printing codes because of too small contrast between printing ink and printing material. The best solutions are black and cyan color which can give suitable contrast and subsequently better and faster reading.

Table 2. Results of 2D codes readability (1: quickly readable codes, 2: readable codes, 3: not readable codes).

Printing ink	Type of code	Contrast [%]					
		15	20	25	30	50	100
Cyan	DM big	3	2	1	1	1	1
	DM small	3	2	1	1	1	1
	QR big	3	3	3	1	1	1
	QR small	3	3	3	1	1	1
Magenta	DM big	3	3	2	2	1	1
	DM small	3	3	2	2	1	1
	QR big	3	3	3	2	1	1
	QR small	3	3	3	2	1	1
Yellow	DM big	3	3	3	3	3	1
	DM small	3	3	3	3	3	1
	QR big	3	3	3	3	3	2
	QR small	3	3	3	3	3	2
Black	DM big	3	1	1	1	1	1
	DM small	3	1	1	1	1	1
	QR big	3	2	1	1	1	1
	QR small	3	2	1	1	1	1

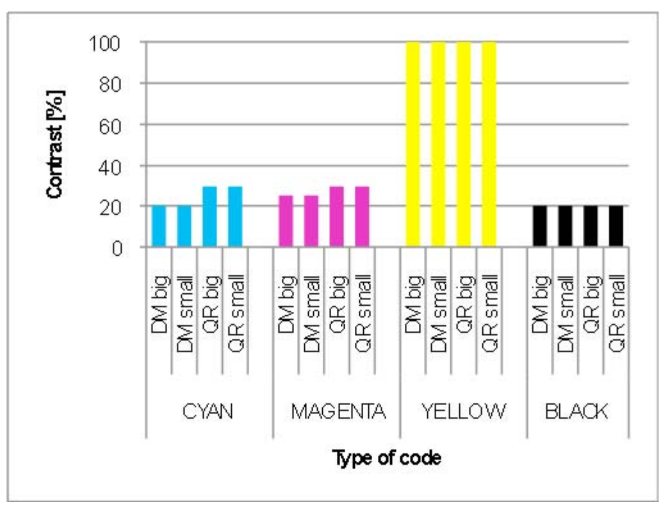


Figure 3: The lowest contrast which enables code reading.

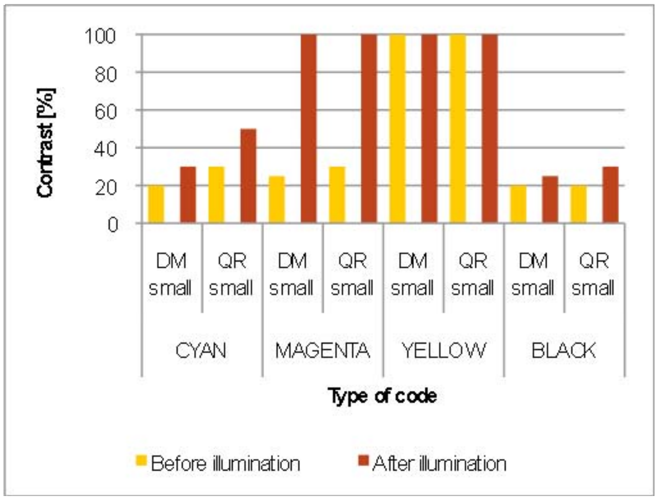
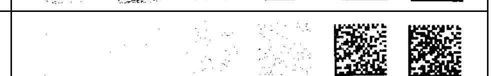
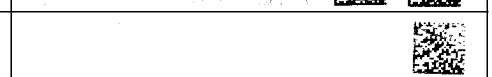
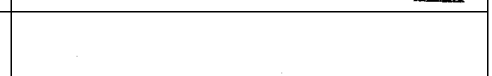
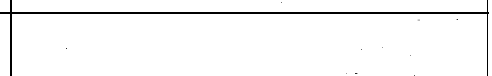


Figure 4: The lowest contrast which enables code reading, before and after illumination.

Table 3: Results of 2D codes readability after illumination (1: quickly readable codes, 2: readable codes, 3: not readable codes).

Printing ink	Type of code	Contrast [%]					
		15	20	25	30	50	100
Cyan	DM small	3	3	3	1	1	1
	QR small	3	3	3	3	1	1
Magenta	DM small	3	3	3	3	3	1
	QR small	3	3	3	3	3	2
Yellow	DM small	3	3	3	3	3	2
	QR small	3	3	3	3	3	3
Black	DM small	3	3	2	1	1	1
	QR small	3	3	3	2	1	1

Table 4: Images of grayscale and threshold samples before and after illumination.

Printing ink	Measurement	Grayscale image	Threshold image
C	Before		
	After		
M	Before		
	After		
Y	Before		
	After		
K	Before		
	After		

2D barcodes reading after illumination

Xe-light simulates sunshine activity and enables accelerated ageing of samples. Because of limited size of sample holders, only the small codes were exposed. After 72 hours of illumination, the codes were read again. The results are shown in table 3.

The results have shown (Fig 4) that readability of codes was better before exposure or it remained unchanged. The best results were obtained by using black ink and the worst by yellow printing ink. The maximum difference in raster tone value of codes (before and after illumination), that reader still can read was 5%. The largest negative impact to speed of reading was observed for magenta codes. Before illumination codes were readable at 30 % or less, after illumination only at 100 % raster tone value. Again we can see better results achieved at DM than QR codes.

Analysing with ImageJ

In addition to checking the legibility of codes we analyzed our image samples with ImageJ in order to establish whether the threshold will show the same results as barcode reader. The results are shown in table 4.

Table 4 shows that in most cases images with threshold show which code will be readable and which not. The images show the degradation of printing ink when it is exposed to light. Some codes appeared sufficiently contrasting that they would enable reading, but this was not the case. It is very obvious that yellow codes are not appropriate for application for 2D codes and also that light causes extensive degradation of codes.

Conclusions

We can conclude that the best results are obtained with dark printed codes on bright printing material, in our case black and also cyan codes printed on white cardboard. In this case the contrast between printing ink and printing material is large enough that the reader can easily read the code. Codes printed in yellow ink give small contrasts between printed barcode and printing material and consequently the reader cannot read the codes as quickly as if they are printed in black ink. We can also conclude that DataMatrix codes are readable at lower contrast than Quick Response codes. The same we can say for codes that encode lower amounts of data. To look closer we can conclude also the following:

- Before light exposure the reader detects inkjet printed codes at lower raster tone value than after exposure.
- Exposure to light aggravates readability; this is observed especially for magenta codes.

Author Biography

Tadeja Muck received her PhD in graphic and interactive communication from Ljubljana University, Faculty of Natural Sciences and Engineering, Chair of Information and Graphic Technology, in 2002, her MSc in wood and paper chemistry science from Biotechnical Faculty in 1998. Dr. Muck worked on coatings developing for papers, which are, used especially for ink jet printing. She is a member of Slovenian Colorist Association. Now the focus of her researches is development of novel methods for print quality evaluation. She is currently involved in the applied project; Printed passive electronic components for smart packaging. She is employed at the Faculty of Natural Sciences and Engineering as associate professor.

Acknowledgements

The authors express their gratitude to Slovenian Technology Agency and company Valkarton for financial support and the Faculty of Natural Sciences and Engineering for lab support.

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