International Joint Conference on Environmental and Light Industry Technologies
18-19 November 2010, Budapest, Hungary
Óbuda University

READABILITY OF 2D QR CODES DEPENDING ON SELECTED CODE PARAMETRES

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Abstract:
Presented are the results of using QR (Quick Response) type of 2D codes in terms of their readability features depending on the change of code parameters and the damages or obstructions to the code [1-4]. QR 2D codes represent a type of 2D symbology developed by the Denso Wave company in 1994. [5]. They contain information in both vertical and horizontal direction. [5]. 2D codes are also characterized by correction capabilities, which enable the reading of the code even if its area is up to 30 % damaged or covered. [6]. The research focused on code parameters that were changed or to which simulated intentional damage was done. The readability was tested on codes with different colour combinations of the code and its background. The aim was to determine how parameters such as colour/contrast and simulated damage, given its position and size, influence the readability of the code.

Keywords:
QR 2D codes, interactive printing, readability, error correction

1. INTRODUCTION

Quick Response (QR) 2D codes represent a type of 2D symbology, developed by the Denso Wave company in 1994. [5]. 2D codes can store information in both vertical and horizontal direction, which enables them to store a much greater amount of information than the conventional bar codes [5]. 2D codes represent the future of storing information about the product on which they are applied. The aim of our research was to determine the resistance of these codes to defects that can distort the reading of information. For this purpose intentional damage was made with appropriate computer equipment and the reading of various codes was performed with online readers and readers installed on the computer. This was necessary in order to insure a better comparability of results. The damage that was done mimicked the problems that can occur in real-life situations, for example, damage to friction during transport, humidity, age, etc. In addition to the issues surrounding code readability, our tasks included the generation of the codes and exploration of code functionality with respect to changes in the colour of the code, as well as of the background.

2. EXPERIMENTAL

The experimental part of the work included generating our own codes, implementation of intentional damage with appropriate computer equipment, and, at the end, an attempt at reading the damaged codes with one of computer softwares such as Quickmark, Bar Capture and online decoder ZXing. The codes were damaged with ImageJ software and so mimicked the defects that could happen in reality, such as friction damage during transport, moisture, age, etc. With appropriate "macro" command which was made solely for the purpose of this work we obtained percentages of the damage. QR code has an error correction capability [5]. Data can be restored even if the symbol is partially dirty or damaged. With this capability a maximum 30% of codewords can be restored [5].

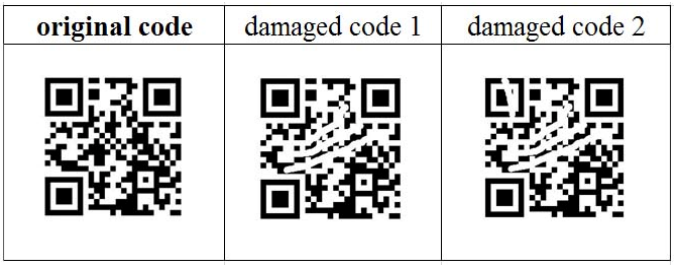

Figure 1. Image of the generated code which by scanning leads to the following URL: http://www.index.hr/, and the same code with simulated damage

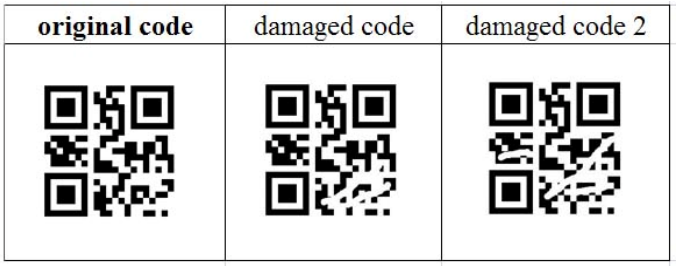

Figure 2. Image of the generated code which by scanning leads to the following text: "QR 2D kod", and the same code with simulated damage

Figure 3.Image of the generated code which by scanning leads to the following URL:http://materijali.grf.hr/pages/kolegiji/primjena-i-ispitivanje-grafiC48Dkih-materijala.php,and the same code with simulated damage

original code	damaged code 1	damaged code 2
		

Figure 4. Image of the generated code which by scanning leads to the following URL:http//moodle.srce.hr/theme/Srce_GRF/logo_grf.jpg, and the same code with simulated damage

original code	damaged code 1	damaged code 2
		

Figure 5. Image of the generated code which by scanning leads to the following text: "2D kodovi su vrsta dvodimenzionalnih kodova sličnih bar kodovima čija je razlika pohranjivanje znatno većeg broja informacija", and the same code with simulated damage

These figures show the codes, generated by corresponding programs, and the same intentionally damaged codes. Codes in group 2 have a larger area of damaged codewords and give worse reading results than the codes in group 1.

```
saveSettings();
run("Set Measurements...", "area limit redirect=None decimal=2");
waitForUser("QR Codes", "Select original image");
ID1 = getImageID();
selectImage(ID1);
run("8-bit");
run("Make Binary");
run("Measure");
OA = getResult("Area");
waitForUser("QR Codes", "Select destroyed image");
ID2 = getImageID();
selectImage(ID2);
run("8-bit");
run("Make Binary");
run("Measure");
DA = getResult("Area");
PRA = ((DA/OA)*100);
PA = (100-PRA);
print("Percent Destroyed Area (PA)"+" is: "+PA);
restoreSettings();
```

Figure 6. Overview of "macro" command

Damaged codes were analyzed by ImageJ software and the corresponding "macro" command which was created for the purpose of this research. With the help of "macro" command the percentage of the damaged area was established in each particular case.

In addition to reading deliberately damaged codes, we investigated the impact of changes in code colour and colour of the background in reading the codes.

Figure 7. Code examples in different colours, made for this research

3. RESULTS

After an appropriate test of readability of QR 2D codes, it was determined that the readability of the code is defined by the size and position of damage.

Processing our own generated codes we reached the following results:

Table 1: Results of code readability from example 1

Code	original area of codeword	area of visible codewords	percentage of damage	readability		
				Quickmark	Zxing	Bar Capture
1	25677	23382	8.938 %	+	-	-
2	25677	22918	10,74%	-	-	-

The results in table 1 (example 1) show that if the damaged area is increased from 8,51 % to 10,19 % the code that was previously readable becomes unreadable in the case of reading with “Quickmark”. Other used decoders were incapable of reading code 1, which has less damaged area than code 2.

Table 2: Results of the code readability from example 2

Code	original area of codeword	area of visible codewords	percentage of damage	readability		
				Quickmark	Zxing	Bar Capture
1	22200	21363	3.77 %	+	+	+
2	22200	20699	6.76 %	-	-	-

Table 2 presents the damaged code 1 whose reading results were positive with all decoders, while code 2, with an almost double increase of the damaged area, proved to be equally unreadable.

Table 3: Results of the code readability from example 3

Code	original area of codeword	area of visible codewords	percentage of damage	readability		
				Quickmark	Zxing	Bar Capture
1	30350	27165	10.49 %	+	+	+
2	30350	26876	11.44 %	-	+	-

Table 3 shows a difference in reading capability between different decoders. Code 1 with 10.49% damaged area was readable by all of the decoders, while damaged code 2 could be read only with free online decoder “ZXing”. Apart from not being able to read the code, the “Bar Capture” decoder gives an explanation that the code contains the damage in the area that serves as a "finder pattern". Here, the position of the damage is located in one of the finder patterns in the corner of the code which allows the decoder to locate the code [7].

Table 4: Results of the code readability from the example 4

Code	original area of codeword	area of visible codewords	percentage of damage	readability		
				Quickmark	Zxing	Bar Capture
1	25236	23469	7.0019 %	+	+	+
2	25236	24550	2,718%	-	+	-

As shown in table 4, the damaged code 2 has a smaller damaged area, but a worse readability outcome from code 1 which has a larger damaged area. Though the damaged area of code 2 is much smaller, it covers the registration mark, i.e. the finder pattern, which in normal conditions allows the reader to find the code [7].

Table 5: Results of the code readability from example 5

Code	original area of codeword	area of visible codewords	percentage of damage	readability		
				Quickmark	Zxing	Bar Capture
1	35475	32453	8.51 %	+	+	+
2	35475	31859	10.19 %	-	+	+

In table 5, similarly to previous examples, in both damaged codes the damage covers a particular number of codewords. In code 2 the damage is greater and the readability of the code is smaller, depending, however, on the decoder used.

Table 6: Results of code readability based on colour changes

color combinations (RGB)	readability		
background color/code color	type of decoder		
gray/yellow	Quickmark	Zxing	Bar Capture
51,51,51/255,255,0	-	-	-
102,102,102/255,255,0	-	-	-
153,153,153/255,255,0	+	-	-
204,204,204/255,255,0	+	-	-
gray/green	Quickmark	Zxing	Bar Capture
204,204,204/0,51,51	+	+	+
153,153,153/0,51,51	-	+	-
102,102,102/0,51,51	-	+	-
51,51,51/0,51,51	-	-	-
blue/black	Quickmark	Zxing	Bar Capture
0,0,255/0,0,0	+	+	-
green/black	Quickmark	Zxing	Bar Capture
0,255,0/0,0,0	-	+	-
red/black	Quickmark	Zxing	Bar Capture
255,0,0/0,0,0	-	+	-
color combinations (CMYK)	readability		
	type of decoder		
background color/code color	Quickmark	Zxing	Bar Capture
cyan/black	+	+	-
magenta/black	+	+	-
yellow/black	-	+	+
magenta/cyan	-	-	-
magenta/yellow	+	-	-

4. DISCUSSION

QR Code possesses an error correction capability to restore data if the code is dirty or damaged. The QR Code error correction feature is implemented by adding a Reed-Solomon Code to the original data [5]. Irving Reed and Gustave Solomon described a systematic way of building codes that could detect and correct multiple random symbol errors [8]. There are four levels of correction, L, M, Q and H. The main difference between them is in the percentage of codewords that can be restored. Level Q (25%) or H (30 %) may be selected for a factory environment where QR Code can get dirty, whereas Level L (7%) may be selected for a clean environment with a large amount of data. Typically, Level M (15%) is most frequently used [5]. In our study the levels do not exceed 11%, so this is a level L.

Regarding the use of coloured backgrounds and codes the best combination proved to be dark colours for the foreground and light colours for background colour. If there is not enough contrast between foreground and background colours, the device will probably fail to decode the code. [9]

5. CONCLUSIONS

Following intentional damaging, those codes could be read in which the damage covers a small number of code words, as long as the registration marks located in the corners of the code are left untouched. The registration mark, i.e. the finder pattern allows identification of the code, and if it is subject to any kind of damage, the reading of the code will not be possible. Therefore, the readability of the code is defined by the extent of damage and its position on the code area. In addition, it was found that the readability of damaged codes depend on the selection of the decoder. The conclusion drawn from our study is that the best results are obtained by the free online decoder "ZXing". It provided a reading of the code under considerable damage, where the other two decoders, namely "QuickMark" and "Bar Capture" were not able to do so. This implies that the readability of damaged codes is affected by factors such as extent of the damage, its position on the code area, and the choice of the decoder which performs the reading.

Regarding the colour both of the code and its background, readability is influenced by the contrast between the two respective colours used, and the decoder which performs the reading. An inverted QR code seems to be a problem however, as the darker dots or modules are the ones which are read. The Japanese company »NTT DoCoMo« says that there should be a contrast of 55% between the two colours, so a code should still work with a coloured surface and darker coloured dots [10].**References**

[1] BOGATAJ, U., MUCK, T. Povećanje interaktivnosti tiskanih medija [online], [cited 23.06.2010.]. Available online: <http://www.belisce.hr/novine/novine_948.pdf>
[2] SCHMIDMAYR P., EBNER M., KAPPE F. What's the Power behind 2D Barcodes? Are they the Foundation of the Revival of Print Media? In I-Know08 and I-Media08, 8th International Conference on Knowledge Management and New Media Technology: book of proceedings, Edited by MAUER, H. And TOCHTERMANN, K. Graz: Technischen Universität Graz, September, 2008, pp 234-242.
[3] http://www.qrme.co.uk, [cited 29.06.2010.]
[4] http://2d-code.co.uk, [cited 29.06.2010.].

[5] About QR code, [cited 24.06.2010]. Available online: <http://www.denso-wave.com/qrcode/index-e.html>.
[6] Reed-Solomon Codes, [cited 01.07.2010]. Available online: <http://www.cs.cmu.edu/afs/cs/project/pscico-guyb/realworld/www/reedsolomon/reed_solomon_codes.html>.
[7] Structure of QR code symbol, [cited 02.07.2010.]. Available online: < http://www.swetake.com/qr/qr1_en.html >
[8] Reed Solomon error correction, [cited 26.10.2010.]. Available online: <http://en.wikipedia.org/wiki/Reed%E2%80%93Solomon_error_correction>
[9] QR Code and 2D Code Generator, [cited 26.10.2010.]. Available online: < http://keremerkan.net/qr-code-and-2d-code-generator/>
[10] All about mobile life, [cited 26.10.2010.]. Available online: <http://mobile.kaywa.com/p667.html>

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