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Designer QR Codes; Ensuring the “beep”

White Paper

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Introduction

QR Codes are experiencing a continuing increase in use. On everything from pizzas to billboards, QR Codes can be found on all sorts of items and products. With increased use, the concept of designer QR Codes – QR Codes that have been graphically altered to make them more graphically appealing – has taken root. By using a percentage of the built in error correction capability, graphic designers are able to alter the structure of the QR Code while still allowing it to be scanned. The problem is that not all designer QR Codes are created equal. Due to a lack of understanding of how QR Codes actually work, designers are confronted with advice, often online, that implies that anything from a slight color change up through the complete redesign of the QR Code will work. Some sources say you can skew the symbol, some say you can’t. Others say that any image color will work. All of this “advice” leaves the designer with the question “what will work, what won’t work and how can I ensure that my target audience will be able to successfully scan my work?”

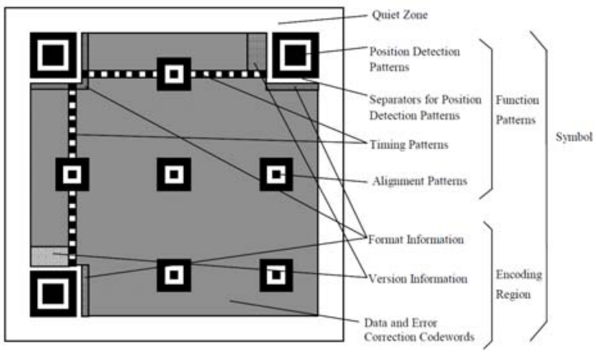

Figure 1. Parts of a QR Code (ISO/IEC 18004:2000(E)).

This white paper has been developed to help address these very concerns. It will not try to address the various implementation issues such as including a call for action or the need for ensuring that any embedded URLs direct to mobile enabled sites. Instead the focus is on what sort of design modifications can be made while still ensuring the maximum number of people will be able to scan the symbol. The research, conducted by Ohio University’s AIDC Lab which is a part of the Russ College of Engineering and Technology, investigated the read rate (the percentage of people who were able to scan a given code) of various types of designer QR Codes.

The Study

In general, the common approach to creating designer QR Codes is to do one or more of the following three items:

- change the color of the symbol
- insert a graphic somewhere inside the symbol
- geometrically distort the cells of the symbol.

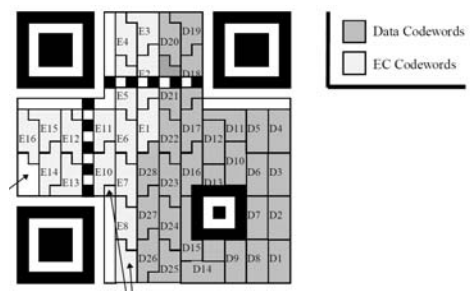

Figure 2. Location of error correction (EC) codewords relative to data codewords (ISO/IEC 18004-2000(3), p 48).

While all of these will work, it is important that the designer understand how the QR Code works, so that they do not inadvertently damage key components or push those components beyond the code’s ability to adjust. As shown in Figure 1, the parts of a QR Code include position detector patterns, alignment patterns and a pair of timing patterns, all of which are designed to help the scanner to quickly find and decode the symbol. The version of the symbol (size of the matrix) and the format information (the level of error correction and masking pattern used) are also embedded into the overall symbol as additional overhead. These locations are of importance and should be noted since the obliteration of this information will result in the inability to decode the symbol. Figure 2 shows where the error correction codewords exist. These codewords are critical in the symbol’s ability to “repair” the damage that was done during the design process and need to be left as intact as possible.

To determine if various designer QR Codes will work, the seemingly innocent question of “can a majority of the smart phone enabled public that scan designer QR Codes read the symbols” was asked. It was quickly realized that this seemingly innocent question was layered with complexity and quickly expanded beyond the initial goal of the research – will a given designer QR Code scan. As such, it was decided to reduce the question to its base component; will the symbol scan.

To answer this, various designer QR Code symbols were selected and a simple online survey was created. The research question that was being asked was “what percentage of the public will be able to scan each symbol.” Twenty-one symbols were selected based on the types of distortion with the goal of having a distribution of distortion types. A twenty-second symbol was added as a control symbol. This symbol was generated without distortions.

Table 1.

Symbols used for survey. Reported values are percent of respondents who successfully read each symbol, both overall and by OS.

Symbol	Overall	Android	Apple	RIM	Other
1	28.9%	32.9%	24.7%	50.0%	42.9%
2	73.9%	82.6%	75.3%	0.0%	42.9%
3	88.6%	87.1%	91.4%	75.0%	71.4%
4	71.1%	77.1%	67.9%	50.0%	57.1%
5	9.6%	8.6%	12.3%	0.0%	0.0%
6	61.4%	64.3%	61.7%	0.0%	57.1%
7	50.0%	50.0%	50.6%	50.0%	57.1%
8	81.1%	85.3%	80.2%	75.0%	85.7%
9	87.1%	89.6%	86.4%	50.0%	85.7%
10	11.0%	11.8%	11.1%	0.0%	14.3%
11	95.7%	94.1%	96.3%	100.0%	100.0%

Symbol	Overall	Android	Apple	RIM	Other
12	29.9%	29.4%	29.6%	25.0%	42.9%
13	76.7%	83.6%	74.1%	75.0%	57.1%
14	67.5%	62.7%	74.1%	25.0%	71.4%
15	57.7%	64.2%	54.3%	25.0%	57.1%
16	40.5%	41.8%	40.7%	25.0%	42.9%
17	35.2%	34.3%	37.5%	0.0%	42.9%
18	43.8%	50.7%	42.5%	0.0%	28.6%
19	76.4%	75.8%	78.8%	75.0%	57.1%
20	61.5%	59.1%	65.0%	50.0%	71.4%
21	79.2%	84.8%	78.2%	50.0%	71.4%
22	1.9%	0.0%	3.8%	0.0%	0.0%

For each of the selected symbols, copyright permission was obtained, with the exception of the control symbol, from QRArts and Azon Media. The symbols were identified as having up to four different types of modifications imposed on them during the design process. These modifications or distortions to the original image are:

- Modified contrast (color changes)
- Consumption of the error correction codewords
- Fixed pattern damage
- Imposed grid non-uniformity

Results

Over 200 responses were collected. Responses that were not at least partially completed were deleted, resulting in 166 completed responses. In instances where a participant did not complete the survey, only those responses that were completed were used, resulting in instances were some images had more data collected then others. The results were grouped by cell phone brand and model and successful read rates (the percent of people who said they could scan a given symbol) were calculated for each group. For each designer QR Code, the overall percentage of successful reads was calculated, as was a breakdown of the sucessful read rate for each operating system.

Table 2.
Operating system read rates by type of distortion.

Applied distortion		Operating system				
		Android	RIM	iOS	Other	Windows
Con	No	71.6%	34.4%	65.5%	43.8%	59.4%
	Yes	51.3%	33.9%	51.3%	46.4%	41.1%
ECC	No	58.7%	35.4%	55.8%	45.8%	50.0%
	Yes	58.8%	32.5%	57.3%	45.0%	45.0%
FPD	No	63.6%	37.5%	60.1%	60.7%	49.4%
	Yes	50.4%	28.1%	50.3%	18.8%	44.8%
GNU	No	60.5%	36.8%	58.8%	44.7%	48.2%
	Yes	47.7%	16.7%	42.1%	50.0%	44.4%

Terminology

Codewords – A "symbol character value, an intermediate level of coding between source data and the graphical encodation in the symbol" (ISO/IEC 16022:2006(E), 2006, pg. 2). In QR Codes, each codeword is a sequence of eight bits in one of three patterns. Each bit is either on or off, and the combination of the eight modules (bits) is combined, in order, to create a code word.

Error Correction – The ability to automatically detect and correct data encoded in a message via mathematical formulas (ISO/IEC 19762-1:2008, 2008).

Fixed Pattern Damage – FPD in an indication of "…damage to the finder pattern, quiet zone, timing, navigation and other fixed patterns in a symbol…" that may impact the ability of the reference decode algorithm to find and decode the symbol (ISO/IEC 15414, 2004, p 19).

Grid non-uniformity – The measurement and grade of "the largest vector deviation of the grid intersections, determined by the reference decode algorithm from the binarized image of a given symbol" (ISO/IEC 15414, 2004).

Symbol contrast – "Symbol contrast tests that the two reflective states in the symbol, namely light and dark, are sufficiently distinct within the symbol." (ISO/IEC 18004-2000(E), p. 92).

Analysis

Of all the symbols tested, number 3 did the best and numbers 1, 5, 10, 12 and 22 did the worst. The reasons all can be traced back to an inability of the scanner to find and decode the symbol due to the distortions imposed. The causes in all cases seem to be broken down into two general causes; fixed pattern damage and insufficient symbol contrast.

Symbol 3 did well because the changes to the base symbol were minimal. The modules were not distorted and none of the error correction codewords were used. Symbol 1 (see Figure 3), has had damage done to the position detection pattern (fixed pattern damage). This box should follow a 1-1-3-1-1 pattern of dark and light modules. However, as can be seen in Figure 3, there are a number of areas in the designer QR Code where this 1-1-3-1-1 pattern does not exist. Likewise, symbol 10 has the same functional issue in that the yellow in the upper left finder pattern will functionally disappear due to the lack of contrast.

Figure 3. Partial view of Symbols 1 and 10, showing the position detection pattern damage and what the pattern should look like on the right.

Symbol 5 resulted in a poor read rate due to a combination of factors. Due to color choices (specifically red as the center of the upper left position detection pattern) the symbol may appear to the scanners as missing the center of the upper left position detection pattern. Since red is often ignored in the decode process, there exists the potential that the entire center of the detection pattern will disappear. In addition to this, the logo in the middle of the symbol is consuming a portion of the available error correction code words. If the orange blocks, in conjunction with the logo were to consume too many of the error correction codewords, the symbol would once again fail to decode.

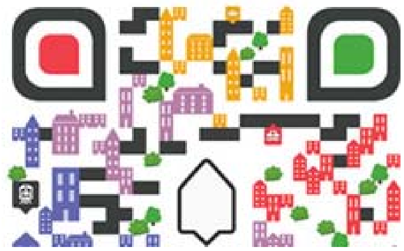

Figure 4. Symbol 5 showing the impacts of color choice and the logo

Symbol 22 takes the issue of contrast to the extreme. As can be seen in Figure 5, not only is there a logo in the middle of a symbol that has low contrast, but the symbol was functionally printed in reverse where the dark and light modules have been reversed. Some scanner software will allow for this, but testing has shown the number of apps is quite small. In addition to the low contrast, and reverse image, there is a dark shape that the symbol has been superimposed over.

Conclusions

Figure 5. Symbol 22 showing the impacts of contrast and inverse images.

The results of this study show that while designer QR Codes will scan, the question of "will it scan" is not a straight forward one. Depending on the types of distortions imparted on the symbols during the design phase, different results are seen. Ignoring the benchmark symbol (number 11) and symbol 22, the read rates for the designer symbols ranged from 9.6% to 88.6%, with an average of 61.5%. The implication of this is that at best, 11% of the symbol's target audience will not be able to read the bar code. And for almost half of the symbols 50% or more of the scanning public will not be able to decode the designer QR Code.

If a designer QR Code is desired for a QR Code campaign, this study shows that avoiding light colors, fixed pattern damage and mass distortion of the symbol's grid pattern are essential if the bar code is going to be successfully scanned by a significant portion of the scanning public. By ensuring a high level of contrast between the modules and the background and minimizing any damage to the position detection pattern, the chances that any given cell phone will be able to scan the QR Code are dramatically increased.

And so the thought that the reader needs to leave with is not "will it scan", but "how many people can I safely alienate?" Because, as this research has shown, any given designer QR Code will probably scan for someone - but not necessarily for the intended audience.

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This research has been submitted for publication and is currently under final review. If you would like to read the complete version of the study, including a completed statistical analysis of the results, please visit the following link (http://www.ohio.edu/industrialtech/aidc/activities/publications.cfm) to the complete paper once it has been published.

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Biography

Dr. KEVIN BERISSO is an Associate Professor of Engineering Technology and Management and the Director of the Automatic Identification and Data Capture (AIDC) Laboratory at Ohio University where he teaches AIDC, RFID, robotics and computer programming. He is active member of the AIM Global Technical Symbology Committee (TSC), the AIM Internet of Things committee, participates in the GS1 BCID Technical Group and received the 2012 Ted Williams Award from AIM Global which is "presented annually to a professor or student in recognition of innovative and exceptional contributions that can further the growth of the industry through their work as a teacher, researcher and entrepreneur." Dr. Berisso is CompTIA RFID+ certified and is a GS1 US certified Barcode Professional. He can be reached via email at berisso@ohio.edu.