Encoding Multi-layered Data into QR Codes for Increased Capacity and Security

Faculty Advisors: Dr. Grant Crawford, Dr. Randy Hoover
Research Undergraduate: Carly M. Nesson (SDSM&T)
Research Experience for Undergraduates – Summer 2013

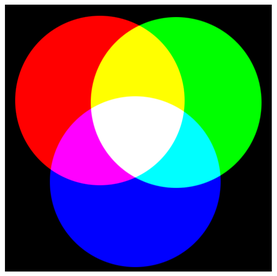

Figure 1. *Representation of red, green, and blue color channels and their combinations*

RGB [Web Photo]. Retrieved from http://shiftbeep.s3.amazonaws.com/wp-content/uploads/2009/10/rgb.png

Abstract

QR (Quick Response) codes are currently comprised of only black and white modules. By layering colorized versions of these QR codes, they will be able to hold more data without increasing the size of the code itself.

This research focuses on two methods of layering:
- Three base colors – Red, Green, and Blue – to hold three times as much information as a black and white QR code
- Six base colors – Full Red, Half Red, Full Green, Half Green, Full Blue, and Half Blue – to hold six times as much information as a black and white QR code

Objectives

This project follows two paths:
- Manipulating QR codes using three base colors
- Manipulating QR codes using six base colors

Both methods for layering will follow the same procedure in order to achieve the same goals:
- Singular QR Codes will be layered to create a layered QR Code
- Layered QR Codes will be un-layered to obtain singular QR Codes
- A system for reading layered QR codes will be established

Procedures

Three Base Colors

Stage 1: Layering
- Three singular QR codes
  - Red background
  - Green background
  - Blue background
- Color the anchors with each original base color
  - Orthogonalization of RGB axes
  - Efficient reading of base colors for un-layering
- Using MATLAB, add images of QR codes to obtain layered QR code

Stage 2: Un-layering
- Isolate desired layers
  - Set non-relevant layers equal to 0
  - Resulting isolated layers are identical to their respective singular QR codes

Stage 3: Reading
- (Future work) Create a patch for current QR reading software that allows for the de-layering process to occur

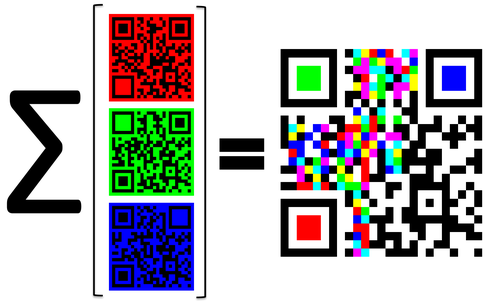

Figure 2*. Singular red, green, blue QR codes summed to equal Layered QR code*

Six Base Colors

Stage 1: Layering
- Six singular QR codes
  - High Red background
  - Low Red background
  - High Green background
  - Low Green background
  - High Blue background
  - Low Blue background
- Color the anchors with each original base color
  - Orthogonalization of RGB axes
  - Efficient reading of base colors for un-layering
- Using MATLAB, add images of QR codes to obtain layered QR code

Stage 2: Un-layering
- Isolate desired layers
  - Set non-relevant full layers equal to 0
  - Add 85 , subtract 170 to obtain high color
  - Subtract high color from isolated layered color, then subtract high color from result to obtain low color

Stage 3: Reading
- (Future Work) Create a patch for current QR reading software that allows for the de-layering process to occur

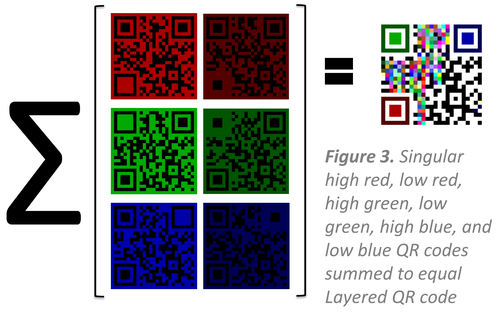

Figure 3. *Singular high red, low red, high green, low green, high blue, and low blue QR codes summed to equal Layered QR code*

Figure 4. *Quantification of colors in matrix form, with zero to full intensities on Red, Green, and Blue channels*

	R	G	B
Black =	[0,	0,	0]
White =	[255,	255,	255]
Red =	[255,	0,	0]
Green =	[0,	255,	0]
Blue =	[0,	0,	255]
Yellow =	[255,	255,	0]
Pink =	[255,	0,	255]
Light Blue =	[0,	255,	255]

Results

- Binary (black and white) QR codes can currently hold 4296 alphanumeric characters
- A layered QR code with three base colors is able to hold 12,888 alphanumeric characters
  - Equivalent to approximately 10 pages of double-spaced 12-point font typing
- A layered QR code with six base colors is able to hold 25,776 alphanumeric characters
  - Equivalent to approximately 20 pages of double-spaced 12-point font typing

Conclusions & Future Work

- In this study, QR code layering has proven to be an efficient and effective method of storing three and six times as much data in the same amount of space as original QR code
- Although it is ideal to attempt to continue layering color channels, layering too many might make it unreadable
  - Perhaps the next step in this research, if it were to continue, would be error correcting and clarifying colors present within layered QR codes
- Ultimately, it is hoped that QR codes will have the ability to hold up to a novel's worth of information

Special Thanks to Dr. Grant Crawford, Dr. Randy Hoover, and Dr. Al Boysen; Research made possible by National Science Foundation REU Security Printing and Anti-Counterfeiting site, Grant # EEC - 1263343