Quick Layered Response (QLR) Codes

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Motivation

Various forms of 2-dimensional (2D) barcodes have become popular due to their ease of readability and their storage capacity. QR codes are especially prevalent and readers and generators exist on most smart phone platforms. Since all camera phones are already colored, and color balancing techniques can mediate lighting and camera effects, colored bar codes are a simple way to increase barcode data capacity.

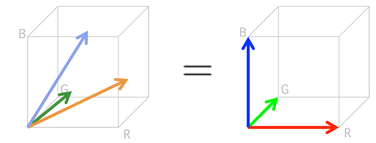
Many companies, universities, and individuals have created '3D' barcodes by using color. Of these attempts, few appear realizable and robust. Microsoft's High Capacity Colored Barcode (HCCB) project has gained the most traction, but is used to encode links to Microsoft servers, not to store the data in the barcode itself.

Examples and sources:

Color Balancing

Color balancing makes our QLR codes robust against different lighting, printing, and camera effects. It also allows data to be encoding in any three linearly independent colors in the RGB domain and still create a theoretically decodable barcode.

$$A \times [\text{color from captured alignment square}] = [\text{ideal color of alignment square}]$$

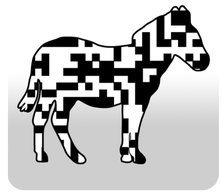


$$A \times \begin{bmatrix} tl_R & tr_R & bl_R \\ tl_G & tr_G & bl_G \\ tl_B & tr_B & bl_B \end{bmatrix} = \begin{bmatrix} 255 & 0 & 0 \\ 0 & 255 & 0 \\ 0 & 0 & 255 \end{bmatrix} \qquad A = \frac{1}{255} \begin{bmatrix} tl_R & tr_R & bl_R \\ tl_G & tr_G & bl_G \\ tl_B & tr_B & bl_B \end{bmatrix}^{-1}$$

Where tl, tr, and bl are the colors sampled from the top left, top right, and bottom left alignment squares. The inverse matrix is calculated by finding the product of the determinant and adjugate matrix.

ZXing

From http://code.google.com/p/zxing/: "ZXing (pronounced 'zebra crossing') is an open-source, multi-format 1D/2D barcode image processing library implemented in Java, with ports to other languages. Our focus is on using the built-in camera on mobile phones to scan and decode barcodes on the device, without communicating with a server."



Encoding

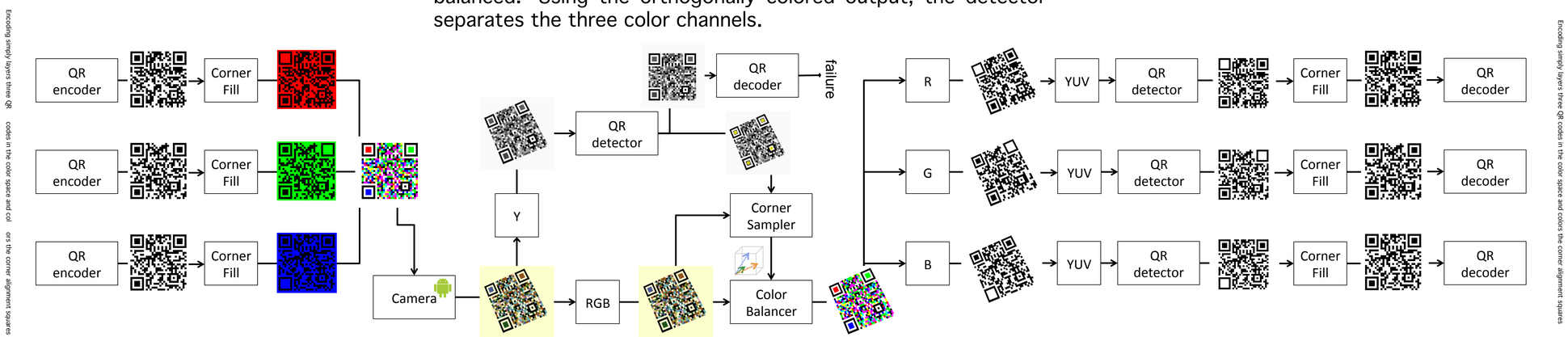
Encoding simply layers three QR codes in the color space and colors the corner alignment squares

Detection

The luminance channel of the captured image is passed to the ordinary QR code detector which returns the coordinates of the alignment patterns. The frame is converted to RGB and color balanced. Using the orthogonally colored output, the detector separates the three color channels.

Decoding

Decoding takes the corrected and sampled data from the detector, fills in the alignment squares, and uses a standard QR decoder



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Future Work

Use more modern iterative error-correcting codes such as an LDPC code to further improve capacity of codes

Enable better color schemes using fewer colors

Make functional on more devices

We would like to thank Professor Girod and the EE368 TAs, David Chen and Derek Pang. We would also like to acknowledge the creators of the ZXing library.