A High Density Colored 2D-Barcode: CQR Code-9

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Summary

1. Introduction.
2. CQR Code-9 Features.
3. CQR Code-9 Results.
4. Conclusion.
Introduction: 2D Bar Code - QR Code

- Proposed in 1994 by the Japanese company Denso Wave Incorporated.
- Two-dimensional structure used to transmit information through a print-scan communication channel.
- Used in advertisements, business cards, storefront displays, etc.

Figure: Example of QR Code.
Introduction: 2D Bar Code - HCCB

- High Capacity Color Barcode - HCCB.
- Created by Microsoft Corporation.
- It uses clusters of colored triangles instead of the square pixels conventionally associated with 2D barcodes or QR codes.
- It uses a palette of 4 or 8 colors for the triangles.
- Closed-source software.

**Figure:** Example of a 4 Color HCCB Code.
Introduction: 2D Bar Code - HCC2D

- High Capacity Colored Two Dimensional Code - HCC2D.
- The two-dimensional barcode prototype is based on the QR Code standard.
- Proposed by the University of Tor Vergata - 2010.
- It uses a palette of 4 or 16 colors for the modules.

![HCC2D prototype for 4-colors](a)
![HCC2D prototype for 16-colors](b)

**Figure:** (a) HCC2D prototype for 4-colors and (b) HCC2D prototype for 16-colors.
Proposed in 2012 by the University of Brasilia.

Structure with $49 \times 49$ modules.

It stores 1,024 information bits and 3,392 Reed-Solomon parity bits.

It uses a palette of 5 colors (black, white, red, green and blue) for the modules in different versions.

It has 38.40% error correction capability using the Reed-Solomon algorithm.

Figure: Example of CQR Code-5.
Figure: (a) QR Code Structure, (b) CQR Code Structure, (c) CQR Code filling direction (d) Example of CQR Code-5 and (e) Example of CQR Code-9.
CQR Code-9: Analysis

- CQR Code with $49 \times 49 = 2401$ modules.
- Finder patterns and separator modules with $3 \times 8 \times 8 = 192$ modules.
- Encoding region with $2,401 - 192 = 2,209$ modules distributed in:
  - Information modules $= 682.66$ (128 symbols of 16 bits each).
  - Reed-Solomon parity modules $= 1525.33$ (286 symbols of 16 bits each).
  - Unused modules $= 1$.
- Module mapping: Red='000', Green='001', Blue='010', Cyan='011', Magenta='100', Yellow='101', White='110' and Gray='111'.
- Information bits storage $= 2,048$ bits.
- Parity bits storage $= 4,576$ bits.
- Error correction capacity of 34.54% or 2,288 bits.

Figure: Example of CQR Code-9.
Berlekamp Reed-Solomon error correction algorithm.

Symbols with numbers between [0 a 65,536] (16 bits each).

Error-correction capability of 143 symbols according $t = (n - k)/2$, or 38.40%.

Primitive polynomial = $D^{16} + D^{12} + D^3 + D + 1$.

Symbols distribution: $RS(414, 128) = [D_1 \cdots D_{128} \ RS_1 \cdots \ RS_{286}]$. 
CQR Code-9: Data Density Comparison

Table: Density of two-dimensional barcodes.

<table>
<thead>
<tr>
<th>Two-Dimensional colored barcode</th>
<th>Data Density [KBytes per square inch]</th>
</tr>
</thead>
<tbody>
<tr>
<td>QR Code</td>
<td>0.627</td>
</tr>
<tr>
<td>HCCB</td>
<td>2.000</td>
</tr>
<tr>
<td>HCC2D</td>
<td>1.881</td>
</tr>
<tr>
<td>CQR Code-5</td>
<td>2.057</td>
</tr>
<tr>
<td>CQR Code-9</td>
<td>3.086</td>
</tr>
</tbody>
</table>
CQR Code-9: Decoding Process

- Image reading
- Module's color identification
- Bits detection and symbol ordering
- Reed Solomon error detection
  - No error
  - Error
    - Error-Correction
    - Message retrieval
    - Output
    - END

Figure: CQR Code-5 and CQR Code-9 decoding process flowchart.
Figure: CQR Code-9 printed on 1.3cm × 1.3cm, captured and correctly decoded at a distance of 9 cm using the Samsung Galaxy S5 camera.
Results: Acquisition and Decoding Process - Example

Figure: (a) Typical histogram of the CQR Code-9, (b) Image segmentation, (c) Structure of finder pattern, (d) Cropped version of the original snapshot, and (e) Rotation of the CQR Code-9.
Results: Acquisition and Decoding Process - Example

Figure: (a) Final segmentation and (b) Estimated result with 15.70% corrected symbols.
Results: Acquisition and Decoding Process

**Figure:** CQR Code-9 average decoding process results for 170 snapshots using the Samsung Galaxy S5 camera.
Conclusions

- Alternative proposal for a two-dimensional color barcode with higher data density per area.
- The CQR Code-9 stores and retrieves bits efficiently, presenting an acceptable error rate for operation in a real print-scan scenario.
- The smaller printed CQR Code-9 (1.3cm × 1.3cm) can be decoded with snapshots between distances of 7cm and 13cm.
- The CQR Code-9 scheme is suitable for storage and transmission of symmetric and asymmetric cryptography codes up to 2,048 bits in small printed areas.
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Thank You! - Questions??
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