International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 02 February 2025
Page No: 184-189
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0025

Colour Icon Matrix Bar-Code

Kumaravel R[1], Shivakumaran S[2], Nanda Guru Pandiyan D[3], Vijay Kumar R[4]

[1]Assistant Professor, Dept. of CSE, Kamaraj College of Engineering and Technology, S. P. G. C. Nagar, Near K. Vellakulam, Virudhunagar - 626001, Tamil Nadu, India.

[2,3,4]UG Scholar, Dept. of CSE, Kamaraj College of Engineering and Technology, S. P. G. C. Nagar, Near K. Vellakulam, Virudhunagar - 626001, Tamil Nadu, India.

Emails: *kumaravelcse@kamarajengg.edu.in[1], pgothai08@gmail.com[2], nandagurupandiyan31@gmail.com[3], vijaykumar.r2521@gmail.com[4]*

Abstract

Cimbar-Code is a proof-of-concept 2D data encoding format designed to be like QR Codes, JAB codes, and Microsoft's HCCB. It works by encoding data in a grid of coloured symbols. Each tile in the grid can have one of sixteen symbols, and each symbol can have one of a few colours. This allows Cimbar-Code to encode a significant amount of data in a small space. Cimbar-Code is designed to be transmitted from a computer screen to a cell phone camera. The decoder app on the phone can then extract the data from the encoded image. This makes Cimbar-Code a potential solution for transferring data between devices without using an internet connection. The Cimbar-Code can encode up to 10kb of data in a single image and it can transfer data at speeds of up to 100kb/s and it includes error correction capabilities to ensure that the data is transmitted accurately.

Keywords: *2D data encoding; android application; data transfer; error correction; QR Codes*

1. Introduction

Barcodes efficiently encode information for automatic data exchange. Traditional 1D barcodes have limited capacity, storing only numbers. 2D barcodes, like QR codes, significantly increase capacity by using grid structures, enabling storage of URLs, contact data, and short text. However, applications requiring higher data density, such as ensuring data integrity without online verification, demand more advanced solutions. Consider a doctor's prescription [2]. Traditional paper prescriptions are vulnerable to forgery. Enhance security, digital signatures can be integrated into the prescription. The doctor, with a digital certificate, signs the prescription details (patient name, address, medication, etc.) [8]. This signed data, along with the certificate, is then encoded in a barcode. The pharmacy can scan the barcode and verify the signature, ensuring the prescription's authenticity. This approach requires a high data density, exceedingly the capacity of typical 2D barcodes. While polychrome barcodes (using multiple colours) offer increased data density, challenges arise due to printing limitations, environmental factors (lighting, abrasion), and variations in how reading units handle colours. This can impact barcode robustness [7], a critical aspect. A polychrome barcode solution must consider: High data density to meet the demands of applications like secure document verification, Flexibility in sizes by adapting to various application requirements, Hardware compatibility to utilize existing infrastructure, such as monochrome readers in industry and polychrome readers in consumer smartphones and Robustness by ensuring reliable data reading under diverse conditions.

2. Objectives

The following are the objectives of our work.

- **Enhanced Data Capacity:** Significantly increase data density compared to traditional 2D barcodes by leveraging colour information.
- **Improved Error Correction:** Implement robust error correction mechanisms to ensure data integrity and reliability, especially in challenging environments.
- **Versatile Shape Flexibility:** Enable the

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 02 February 2025
Page No: 184-189
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0025

creation of barcodes in various shapes and sizes to suit different applications and design constraints.

- **Expanded Application Scope:** Explore applications beyond traditional barcode uses, such as data security, authentication, and content delivery shown in Figure 1.
- **Enhanced Security:** Incorporate advanced security features to protect sensitive data and prevent counterfeiting.
- **Improved Readability:** Optimize barcode design for better readability under various lighting conditions and scanning angles.
- **User-Friendly Interface:** Create user-friendly tools and software for barcode generation and reading.

3. Methodology

The methodology of our work is as discussed below.

3.1 Encoding

- **Data preparation:** The input file is compressed using zstd compression.
- **Error correction:** Reed-Solomon error correction is applied to the compressed data to enhance robustness against errors introduced during transmission.
- **Data splitting:** The data is split into chunks that can fit within a single cimbar code.
- **Barcode generation:** Each data chunk is converted into a grid of coloured tiles, where the colour and tile chosen to represent specific bits with various shapes.

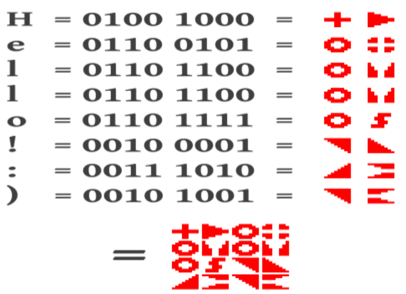

Figure 1 The above is a 4x4(x4) cimbar grid encoding sixty-four bits of data. The encoder iterates over the input data, assigning symbols (and colours) according to the bits it reads.

3.2 Decoding

- **Image capture:** The smartphone camera captures the animated barcode displayed on the computer screen.
- **Code decoding:** The captured image is decoded to retrieve the grid of coloured tiles shown in figure 2.

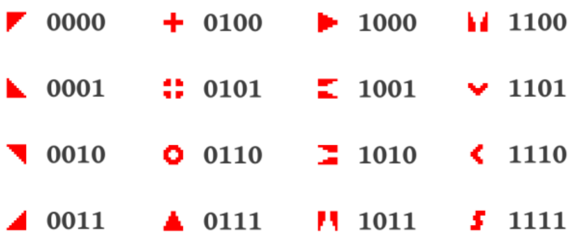

Figure 2 This is the set cimbar-code uses. Each symbol is around twenty bits (by image hash hamming distance) from all other symbols, and importantly, this relationship tends to hold (though not perfectly) even when symbols are blurry or otherwise corrupted.

- **Data extraction:** The colours and tile arrangement are interpreted to recover the encoded bits.
- **Error correction:** Reed-Solomon error correction is applied to fix any errors that might have occurred during transmission.
- **Data merging:** The decoded data chunks from multiple cimbar-code are merged to reconstruct the original file.

4. System Design

A flowchart is a visual representation of a process or algorithm, using standardized symbols to illustrate the sequence of steps and decisions involved. This diagram is a high-level view of a system. The below depicted diagram we have showcased the working principle of our work.

5. Modules

The functionality of our work is as discussed below.

5.1 Data Encoding

5.1.1 Data Input

The system accepts the input data, which can be various formats like text, numbers, binary files, or

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 02 February 2025
Page No: 184-189
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0025

even images. This data is the information that needs to be encoded into the Cimbar barcode.

5.1.2 Data Chunking

The input data is divided into smaller, manageable chunks or blocks. This is crucial for efficient encoding and error correction. The size of each chunk depends on factors like the desired data density and the complexity of the encoding scheme.

5.1.3 Colour-Icon Mapping

This is the core innovation of Cimbar. Each data chunk is mapped to a unique combination of a colour and an icon from a predefined set. This dual encoding significantly increases the data density compared to traditional barcodes that rely solely on black and white patterns.

5.1.4 Error Correction:

Reed-Solomon error correction codes are applied to the encoded data. This adds redundancy to the data, allowing for accurate data recovery even if parts of the barcode are damaged, obscured, or distorted during scanning.

5.1.5 Matrix Generation

The encoded data, along with the error correction codes, is arranged into a grid or matrix. Each cell within the matrix represents a specific combination of colour and icon, encoding a portion of the original data. Figure 3 shows A Flow Diagram of the Working Model of Our Project.

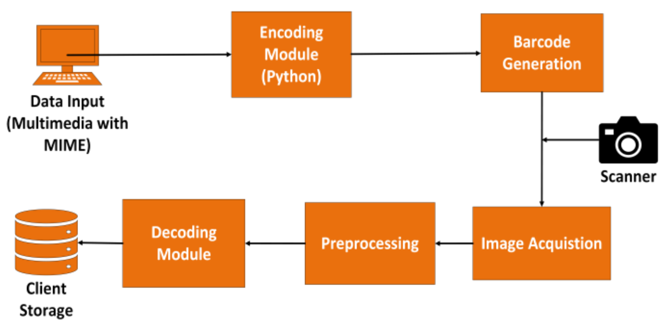

Figure 3 A Flow Diagram of The Working Model of Our Project.

5.2 Barcode Generation

5.2.1 Image Rendering

The colour-icon matrix is rendered into a visual image format, such as PNG. This involves assigning specific colours and icons to each cell in the matrix and generating the corresponding image.

5.2.2 Image Optimization

The generated image may be optimized for various factors, such as:

- **File size reduction:** To minimize storage space and transmission bandwidth.
- **Colour profile adjustment**: To ensure accurate colour representation across different devices and display conditions.
- **Readability enhancement**: To improve the clarity and scan ability of the barcode.

5.3 Image Acquisition and Decoding

5.3.1 Image Capture

The Cimbar code is captured by a camera or other imaging device. The quality of the captured image significantly impacts the accuracy of the decoding process.

5.3.2 Image Processing

The captured image undergoes a series of image processing steps:

- **Noise reduction:** To remove noise and artifacts introduced during image capture.
- **Colour correction:** To adjust colour values to compensate for variations in lighting and camera settings.
- **Image enhancement:** To improve the clarity and contrast of the barcode image.

5.3.3 Icon Recognition

The system analyses the image to identify and extract the individual colour-icon combinations within the matrix. This involves pattern recognition algorithms to accurately identify the colours and icons.

5.3.4 Data Extraction

The decoded colour-icon combinations are then translated back into the original data format. This involves mapping the colour-icon combinations to their corresponding data chunks.

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 02 February 2025
Page No: 184-189
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0025

5.3.5 Error Correction Decoding

Reed-Solomon error correction is applied to the decoded data to correct any errors during decoding process. This ensures data integrity and accuracy even in the presence of noise or distortions.

5.4 Data Output

5.4.1 Data Retrieval

The decoded and corrected data is retrieved in its original format. This could be text, numbers, binary data, or any other format that was initially encoded.

6. Experimental Analysis

The robustness of our work is as discussed below.

6.1 Preface

It is essential that Cimbar-code meets all requirements of the intended application scenario. Robustness is of high importance. This includes reliable decoding. Unfortunately, to our best knowledge, no standard test is available to evaluate robustness and effectiveness for coloured barcodes. Many variables can affect the decoding performance. Of particular interest for our scenario are the following questions,

- To Verify Cimbar-code functionality with different data types.
- To Verify the effectiveness of error correction mechanisms in Cimbar-codes.
- To Verify Cimbar-code functionality under different environmental conditions.
- To Verify Cimbar-code compatibility across different devices and operating systems.

6.2 Analysis

Scanning codes with the used flatbed scanner gave better results than using a mobile phone. This is partly since the images were sharper when they were taken with a scanner. Aside from the quality of the mobile phone's camera, the reason for the lower performance on the phones is also due to motion blur the phone when pressing the capture button. Therefore, recording from a video stream and extracting optimal image information out of it is gives much better results. The analysis shows that in most cases, if the code could not be successfully decoded, the finder pattern could not be found or not completely found and therefore decoding failed. In the other cases the error correction failed due to too many errors. This demonstrates the need for colour flexibility and thus the need to adapt the choice of colour.

7. Results and Discussion

The results and discussion of our work are discussed below.

7.1 Results

Cimbar-code successfully demonstrates a method for high-density data transfer using coloured barcodes. It achieves data density exceeding traditional 2D barcodes by leveraging colour information. The implementation incorporates error correction using fountain codes, enabling data reconstruction even with missing frames. The decoder can handle misshapen, blurry, or partially obscured cimbar codes to an extent.

7.2 Discussion

Cimbar-code's design prioritizes simplicity, using basic image hashing for symbol definition. This simplicity offers advantages in implementation and robustness. The current implementation has a file size limit of 33.55MB due to fountain code constraints. However, larger files could be split and reassembled using an agreed-upon scheme. The decoder employs various techniques to minimize errors, including interleaving error correction data, prioritizing high-confidence cell decodes, and accounting for local distortions.

8. Future Work

This project is a proof-of-concept for high-density data transfer via coloured barcodes. While the core functionality is complete, there are several areas for future improvement:

- **Metadata:** The ability to store and retrieve metadata like error correction level, number of colours, and number of symbols directly from the encoded image.
- **Multi-frame decoding:** Leveraging information from previous decoding attempts to improve success rates for static images.
- **Symbol optimization:** Exploring a more

optimal set of symbols for encoding data, potentially including more symbols with higher bit capacity per tile.

- **Symbol size optimization:** Investigating smaller symbol sizes while maintaining reliable decoding.
- **Colour set optimization**: Analysing colour combinations for better contrast, brightness, and overall decoding accuracy.
- **Grid size and shape:** Evaluating the impact of grid size and shape (e.g., square vs 4:3) on error resilience and data capacity.
- **Error correction:** Exploring more efficient error correction codes like QC-LDPC to potentially improve throughput.
- **Mobile optimization:** Implementing GPU support using OpenCV and OpenCL on Android for faster decoding.

Conclusion

The climbar-code project successfully demonstrates the feasibility of high-density data transfer using coloured barcodes. By leveraging colour information and employing efficient error correction techniques, cimbar-code achieves data densities surpassing traditional 2D barcode methods. The project's innovative approach and robust implementation pave the way for future research and development in this area, with potential applications in various fields such as secure data transfer, product authentication, and content delivery. While challenges such as file size limitations and decoding complexities remain, the findings of this project offer valuable insights for further advancements in high-density data transfer technologies.

References

[1]. GS1 Global Standards 1. (n.d.). EAN-UPC. Retrieved from [https://www.gs1.org/standards/barcodes/ean-upc]

[2]. Waldemar Berchtold, Huajian Liu, Martin Steinebach, Dominik Klein, Tobias Senger, Nicolas Thenee, JAB Code - A Versatile Polychrome 2D Barcode, 2022, Electronic Imaging, Volume: 32, Issue: 3, Pages 207-1 - 207-7

[3]. International Organization for Standardization/International Electrotechnical Commission. (2006). ISO/IEC 16022:2006: Information technology - Automatic identification and data capture techniques - Data Matrix bar code symbology specification.

[4]. International Organization for Standardization/International Electrotechnical Commission. (2008). ISO/IEC 24778:2008: Information technology - Automatic identification and data capture techniques - Aztec Code bar code symbology specification.

[5]. International Organization for Standardization/International Electrotechnical Commission. (2015). ISO/IEC 18004:2015: Information technology - Automatic identification and data capture techniques - QR Code bar code symbology specification.

[6]. Grillo, A., Lentini, A., Querini, M., & Italiano, G. F. (2010, May). High Capacity Colored Two Dimensional codes. In Proceedings of the International Multiconference on Computer Science and Information Technology (pp. 9-14).

[7]. Sali, E., & Lax, D. M. (2007, US Patent No. 7,210,631 B2). Color bar code system. U.S. Patent and Trademark Office.

[8]. Parikh, D., & Jancke, G. (2008, September). Localization and Segmentation of A 2D High-Capacity Color Barcode. In 2008 IEEE Workshop on Applications of Computer Vision (WACV) (pp. 1-6). IEEE.

[9]. Bulan, O., Monga, V., & Sharma, G. (2009). High-capacity color barcodes using dot orientation and color separability. In Proc. SPIE (Vol. 7394, p. 73940Y).

[10]. AIM Global. (n.d.). Ultracode. Retrieved from [https:// www.aimglobal.org/ store/ SpeechCode. (n.d.). SpeechCode High-Capacity Color Barcode. Retrieved from [https:// speechcode.eu /product/ specification]

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 02 February 2025
Page No: 184-189
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0025

[11]. Jancke, G. (2003, November). High-Capacity Color Barcodes (HCCB). Microsoft Research. Retrieved from [https://www.microsoft.com/enus/research/project/high-capacity-color-barcodes-hccb/]

[12]. Moon, T. K. (2005). Error correction coding: Mathematical methods and algorithms. Wiley-Interscience.

[13]. Winter, C., Berchtold, W., & Hollenbeck, J. N. (2019, June). Securing physical documents with digital signatures. In Proceedings of the 14th ACM Conference on Security and Privacy in Wireless and Mobile Systems (pp. 323-334).