# Enhancing Data Capacity in Color QR Codes with Wavelet based Steganography Algorithms

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jmm 2024 Joint Mathematics Meetings
San Francisco • January 3–6

## Abstract

As the barcode becomes more widely used, its applications and data capacity demands grow, increasing the need for color barcodes with greater data density. Moreover, the necessity of increasing information capacity and security motivate the use of more colors to create color barcodes. In this research, we utilize the quick response (QR) code–one of the many types of barcodes–we develop an algorithm to create a color QR code with n color channels that stores much more information than a standard QR code and embeds extra data with limited access privilege. This algorithm consists of two techniques: (1) enlarging the data capacity of a compact QR image by stacking multiple single colored QR codes to form a color barcode, and (2) embedding information into the color QR code in an M-band wavelet domain. The new algorithms are also in a flexible framework, which allows for further modifications to improve both the data capacity of a color QR code to meet future demands.

## Introduction

Technological Advancements, Storage Challenges, and Securities

The rapid growth of digital platforms and e-services has resulted in an exponential increase in data volume, complexity, storage demands, and data securities. This trend poses significant challenges in managing, securing, and accessing data efficiently. The escalating storage demands are driven by diverse factors, including the proliferation of digital media, evolving data types, stringent performance requirements, privacy concerns, and infrastructure limitations. These challenges necessitate innovative solutions to optimize storage efficiency and address the evolving storage needs effectively.

Proposed Solution: Colored & Stacked QR Codes. Enhanced Storage Capacity: colored stacked QR codes offer a viable solution to address the growing storage demands by providing increased data storage capacity compared to traditional QR codes. By leveraging multiple layers of color, each representing distinct data sets or categories, color stacked QR codes can store significantly more information within a single code, optimizing storage efficiency and capacity.

Versatile and Robust Storage Solutions: the ability to encode multiple layers of data within a single color stacked QR code enables the development of more complex and versatile storage solutions capable of accommodating diverse data types and requirements. Furthermore, incorporating advanced error correction techniques and data redundancy measures across multiple color layers ensures robustness and reliability in data storage, mitigating the risks associated with data loss or corruption.

Improved Organization and Accessibility: the use of distinct colors and customizable designs in color stacked QR codes facilitates better organization and navigation of stored data. Different colors can be associated with specific categories or types of information, enhancing user experience and accessibility. Moreover, color stacked QR codes remain compatible with existing QR code scanning technologies and applications, ensuring widespread accessibility and usability across various devices and platforms.

## Methods and Materials

How do we do this?

Coloring and stacking monochromatic QR codes will take multiple steps. We would modify the traditional black-and-white QR code to incorporate multiple layers of color while keeping the original QR code scannability, functionality, and accessibility. These steps include segmentation, coloring, stacking, testing, and optimization.

- Segmentation; divide a normal monochrome QR code into segments, each representing different areas of data.
- Coloring; assign different colors to each segment, make sure that these colors can be easily differentiated to not interfere with the scannability of the code.
- Stacking; stack the colored segments into layers to create a colored and stack QR code. Ensure that layers align correctly to maintain the required quiet zone and error correction features for accurate scanning and decoding.
- Testing; test the QR code in multiple different scenarios (eg. different lighting, different scanners) to make sure that the code is fully functional.
- Optimization; optimize the code by using the test results as a guideline. Adjust any colors and layers to enhance scannability and readability.

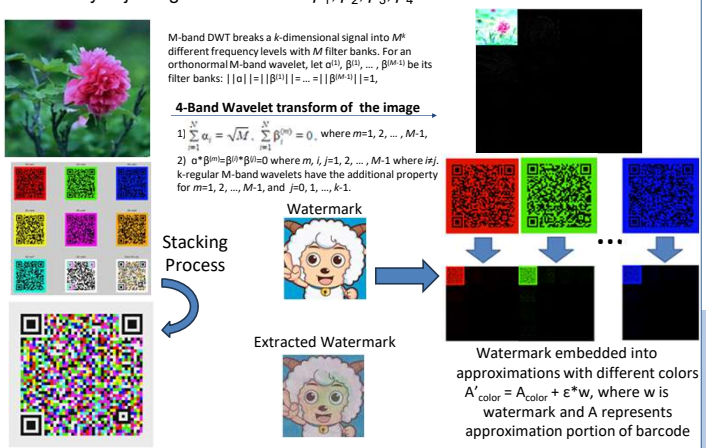
Materials used

We used the MATLAB coding software, QR code generation library, a QR code scanner, and resources on the web related to this project.

## Findings

Merge Color QR Codes

In order to combine multiple colored QR codes together, we decompose each colored QR code image into three matrices by MATLAB, using $I_{1R}$、$I_{1G}$、$I_{1B}$; $I_{2R}$、$I_{2G}$、$I_{2B}$; $I_{3R}$、$I_{3G}$、$I_{3B}$; $I_{4R}$、$I_{4G}$、$I_{4B}$…… for red, green, and blue, then multiply the R, G, and B matrices for each image by a coefficients $\mu_1$, $\mu_2$, $\mu_3$, $\mu_4$……and add all the matrices for red to get $I_R$, and all the matrices for green to get $I_G$ , add all the matrices representing blue to get $I_B$ ,and finally, recombine $I_R$、$I_G$、$I_B$ into a color image to get the colored QR code we want. We can change the effect of the colored QR code by adjusting the coefficients $\mu_1$, $\mu_2$, $\mu_3$, $\mu_4$…… the results are shown below:




## Results

In this research, we created colored stacked QR codes and discovered that they can hold much more information than regular black-and-white QR codes. This means they offer a bigger space to store data, making them more efficient. This will definitely help in the long run when the data used by millions of people on the media increases dramatically, especially since AI technology is growing. Colored and stacked QR codes are more reliable than their monochromatic familiars. They have built-in features that help correct errors and protect data, reducing the chances of losing important information. The color stacked QR codes showcased robust and versatile storage capabilities, accommodating diverse data types and requirements effectively. The incorporation of advanced error correction techniques and data redundancy measures across multiple color layers would result in a reduction in data loss. The color stacked codes are easier to use and still accessible to people. The different colors helps quickly identify and access specific information, enhancing QR codes overall. The use of distinct colors and customizable designs in color stacked QR codes created better organization of stored data. This attributes to the visual differentiation of data to the improved usability and accessibility of the storage units.

## Future work

In the future, we hope to explore several directions in where we enhance the High-Capacity Barcodes with Wavelet-based Denoising Functions. We want the denoising algorithm based on Discrete M-Band Wavelet Transform to extend and adapt to handle more diverse and complex noise patterns.

This research could investigate the security aspects of the color QR code system we proposed. This includes exploring encryption techniques for embedded data and evaluating the system's resilience against various attacks.

## References

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## Acknowledgements

Prof. Xiaodi Wang and Prof. Li