Short Ranged Multicolored QR Code for Data Transmission

Muhammad Aqib Khan
DSSE Habib University
Karachi, Pakistan
mk06181@st.habib.edu.pk

Omer Rastgar
DSSE Habib University
Karachi, Pakistan
or05554@st.habib.edu.pk

Shaheer Kamal
DSSE Habib University
Karachi, Pakistan
sk05573@st.habib.edu.pk

***Abstract*—Multi-colored video QR Codes (MCVQRCs) are a new type of QR Code that can encode video data in addition to traditional text and numeric data. In this paper, we present an implementation of MCVQRCs and demonstrate their potential to revolutionize the way that video data is stored and shared. Our implementation of MCVQRCs utilizes a combination of data compression and error correction techniques to effectively encode video data within the confines of a traditional QR Code. We also introduce a new algorithm for generating MCVQRCs that can be customized with different color schemes to enhance their visual appeal and distinguish them from standard QR Codes. Overall, our work showcases the potential of MCVQRCs to provide a convenient and efficient way to store and share video data, and we believe that this technology has the potential to have a significant impact on a variety of applications, including video marketing, education, and entertainment.**

***Keywords*—** Data Communication; Multicolored QR Code; Bandwidth;

I. INTRODUCTION

The development of efficient and reliable communication systems is of paramount importance in today's interconnected world. With the increasing demand for data transmission and the proliferation of internet-of-things (IoT) devices, there is a need for communication systems that can handle high data rates and low power consumption. Visual light communication (VLC) has the potential to meet these needs by using light as a transmission medium [1], which allows for high-speed data transmission and low power consumption compared to traditional radio frequency (RF) communication systems.

One important application of VLC is in the field of short-range communication, where it can provide a viable alternative to RF-based systems such as Bluetooth. The use of multicolored video QR codes for data transmission is a promising approach in this regard, as it allows for multiple devices to communicate on different channels without interference. This can be especially useful in situations where RF channels are congested or unavailable.

Furthermore, the implementation of VLC systems does not require additional hardware setup in most cases, as the necessary infrastructure is already present in the form of lighting fixtures and displays. This makes VLC a more feasible solution for short-range communication compared to other technologies such as LiFi, which requires dedicated hardware to be installed.

Overall, the research on VLC and the implementation of short-range communication systems using multicolored video QR codes has the potential to significantly improve the efficiency and reliability of data transmission, with numerous potential applications in fields such as IoT, transportation, and healthcare.

II. LITERATURE REVIEW

QR codes are a widely-used method of storing and transmitting data, with version 40 QR codes able to store up to 3 KB of data [2]. Recent research has demonstrated, however, that this capacity can be expanded by adding color channels and employing multiplexing techniques such as Singular Value Decomposition and Wavelet Transform [2]. Through the use of animated QR codes that change with each refresh cycle, it is possible to transmit even more information.

This method has the potential to replace radio frequency (RF)-based systems such as Bluetooth in the field of short-range communication. In situations where RF channels are congested or unavailable, the use of multicolored video QR codes enables multiple devices to communicate on different channels without interference, making them particularly useful. In the majority of cases, the infrastructure for this communication is already in place, making it a more feasible solution than LiFi, which requires the installation of specialized hardware.

Table V: Execution time of basic blocks in the pipeline of HiQ decoder using Nexus 5

Number of Modules	Type	Data Capacity	YUV-2-RGB	Bina-rization	Patterns Detection	Transfor-mation	Color Recovery	Random-ization	Error Correction	Time per Frame	Number of Frames
137 × 137	B/W	1732 bytes	NA	**110ms (34%)**	**112ms (34%)**	23ms (7%)	NA	20ms (6%)	41ms (13%)	322ms	3.0
	Color	5196 bytes	**400ms (27%)**	204ms (14%)	153ms (10%)	14ms (1%)	**500ms (34%)**	45ms (3%)	150ms (10%)	1466ms	4.5
157 × 157	B/W	2303 bytes	NA	**104ms (27%)**	**123ms (32%)**	37ms (10%)	NA	38ms (10%)	60ms (16%)	380ms	4.3
	Color	6909 bytes	**386ms (24%)**	200ms (12%)	150ms (9%)	20ms (1%)	**650ms (40%)**	69ms (4%)	160ms (10%)	1635ms	6.7
177 × 177	B/W	2953 bytes	NA	**112ms (25%)**	**138ms (30%)**	37ms (8%)	NA	50ms (11%)	97ms (21%)	455ms	5.6
	Color	8859 bytes	**400ms (20%)**	193ms (10%)	213ms (11%)	25ms (2%)	**881ms (44%)**	111ms (5%)	200ms (10%)	2023ms	9.0

Fig. 1. Shows the different levels of accuracy and the different bit rate from colour and black and white QR codes

Error detection and correction are crucial components of any communication system. Reed Solomon Error-Correcting Code was used in the implementation proposed by Melgar et al. [3] to provide error correction in colored QR codes with five colors (red, green, blue, black, and white). The algorithm was able to consistently decode 1024 bits of information stored on a printed area measuring 1.3 cm x 1.3 cm. In the study conducted by Abas et al. [2], simulation results demonstrated that the proposed algorithm could store 24 times as many characters as a black-and-white QR code and 9 times as many as colored QR codes. The algorithm utilized a compression, multiplexing, and multi-layer encoding model to achieve this capacity increase.

The error detection and correction occurs using Reed–Solomon error correction algorithm. The different levels are shown below:

1. Error correcting level L is 7%
2. Error correcting level M is 15%
3. Error correcting level Q is 25%
4. Error correcting level H is 30%

Fig. 2. Describes the Error correcting levels for damage and dirty QR codes

Other issues identified with the use of colored QR codes include chromatic distortion and lighting variation [4]. Chromatic distortion may be caused by cross-channel color interference, and illumination variation may result from varying lighting conditions. Yang et al. [4] discovered a new type of chromatic distortion in high-density colored QR codes called cross-module color interference, which is caused by the codes' high density and makes geometric distortion correction more difficult. However, this type of distortion is less likely to occur if animated QR codes are displayed on screens as opposed to stickers. Yang et al. [4] proposed the use of LSVM-CMI and QDA-CMI as solutions to chromatic distortion, which correct the distortion using support vector machines and quadratic discriminant analysis, respectively.

Grillo et al. [5] proposed a high-capacity two-dimensional colored QR code, which they claimed could store more than three times as much information as a conventional QR code. However, the approach has the drawback of requiring a specialized reader to decode the code, which may prevent its widespread application. The proposed method utilizing animated QR codes can be decoded with a standard QR code reader.

In the experiment conducted by Li et al. [6], different screen-to-camera angles were used to demonstrate the practicability of the proposed method. The primary objective of the study was to covertly transmit data, and the results demonstrated that the proposed method could successfully transmit data at angles of 0°, 15°, and 30°.

Overall, the use of animated QR codes for short-range communication has the potential to significantly improve the efficiency and reliability of data transmission, with applications in IoT, transportation, and healthcare. To optimize the design of the codes and the communication system, as well as to address obstacles such as error detection and correction, chromatic distortion, and illumination variation, additional research is required.

III. Conventional Approach

The conventional process of making a QR code has many different steps, which are discussed in the subsections below [7]:

A. Analysis of Data encoding methods

There are multiple modes of encoding the data text i.e. Alphanumeric, Numeric, Bytes, and Kanji. These modes have different methods of encoding text to bits each of which provide different degrees of optimization for the size of the encoded data. Thus, it is essential to analyze first that which mode of encoding should be selected based on the fact that which will be able to provide us with the most optimized set of encoded data.

B. Data Encoding

After the selection of encoding mode, the next step is to now encode the data. Each encoding method utilizes its own technique to encode the text to bits. In this step, first the level of Error correction (i.e. L, M, Q, H as defined above) is selected, after which, the smaller version (different sizes of QR codes refers to different versions) of the data is then selected. After that the data is encoded using the selected mode. This process generates an 8-bit data codeword from the original bit string.

C. Error Correction Coding

After the above step of creating the string of data bits that represent the text, those bits must be utilised to construct error correction codeword using a technique known as Reed-Solomon error correction [8]. QR code scanners, when scanning the QR code, detects and reads the data codeword and error correction codeword separately and then compares them to check the error which might have occurred while reading the data and then corrects it.

D. Module Placement

QR codes must include function patterns. These are shapes that must be placed in specific areas of the QR code to ensure that QR code scanners can correctly identify and orient the code for decoding.

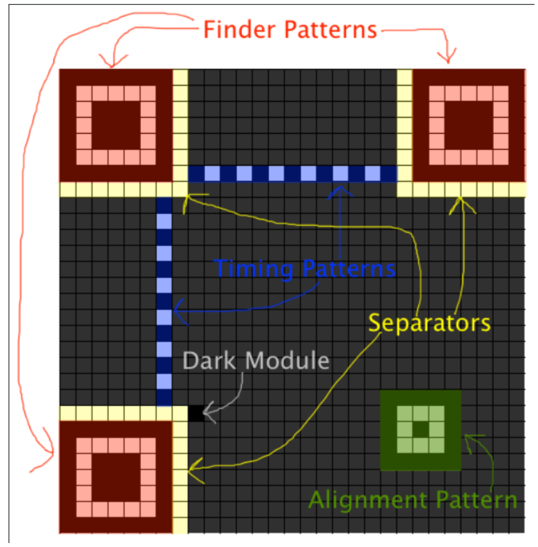

Fig. 3. Show the different sections of a qr code

- The finder patterns are the three blocks in the corners of the QR code at the top left, top right, and bottom left.
- The separators are areas of whitespace beside the finder patterns.
- The alignment patterns are similar to finder patterns, but smaller, and are placed throughout the code. They are used in versions 2 and larger, and their positions depend on the QR code version.
- The timing patterns are dotted lines that connect the finder patterns.
- The dark module is a single black module that is always placed beside the bottom left finder pattern.

E. QR Mask Patterns

A mask pattern changes which modules are dark and which are light according to a particular rule. The purpose of this step is to modify the QR code to make it as easy as possible for a QR code reader to scan. There are four different rules for masking

1) The first rule gives the QR code a penalty for each group of five or more same-colored modules in a row (or column).
2) The second rule gives the QR code a penalty for each 2x2 area of same-colored modules in the matrix.
3) The third rule gives the QR code a large penalty if there are patterns that look similar to the finder's patterns.
4) The fourth rule gives the QR code a penalty if more than half of the modules are dark or light, with a larger penalty for a larger difference.

F. Design

The initial implementation uses Python libraries like ”qrcode” to generate images and using ”moviepy”, a video can also be generated. The authors have used the ”Numpy” library for image interpolation and the OpenCV library for decoding the QR code. The implementation is also explained in [9].

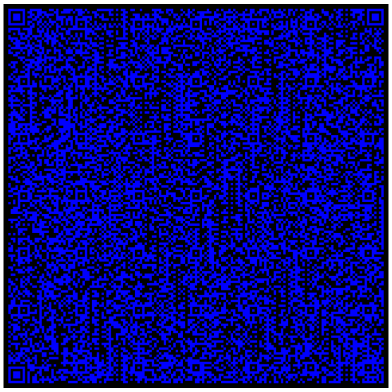

Fig. 4. QR code generated using PyQR library

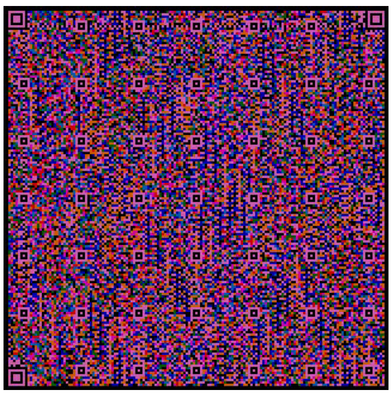

Fig. 5. Multiplexed QR code made from R,G,B channels

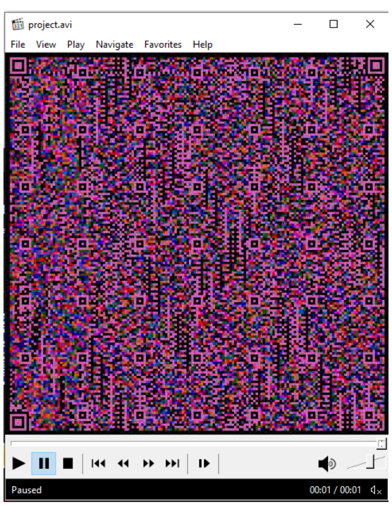

Fig. 6. Joining Multiple frames to make a video

IV. Modified Algorithms

Due to the restrictions of Python libraries, the authors decided to design their own QR code generation algorithm. The rational of designing a custom QR code algorithm is for numerous reasons:

1) Different compression algorithms can be used (Huffman) which can increase the data size being encoded in the QR codes by compressing the data bits.
2) The redundant checks that are only necessary for printable QR codes can also be removed, as there is no use for them in this application.
3) The size of pixels can be changed to best suit the proposed edge detection algorithm.
4) The QR code can be scaled to be as large or small size according to the requirement.

The process of making a QR code has many different steps, which are discussed in the later sections below [7].

A. Algorithm for svg to png file Conversion

The authors chose SVG because they needed a scalable QR code that could be converted to png for the video.

B. Data Compression

For data compression, the authors have used the deflate method, which was originally defined by Phil Katz. This method includes Huffman coding along with LZ77 Algorithm. The demonstration of the code and results are shown in the attached pdf along with this pdf.

C. Color QR Code Generation

In order to increase the data storage size of each QR frame, we needed to use a color QR code, for which implemented a custom algorithm we made ourselves. The demonstration of the code and results are shown in the attached pdf along with this pdf.

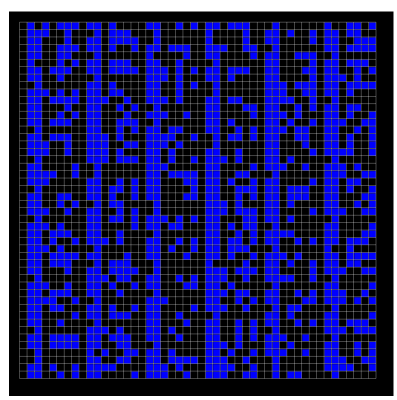

Fig. 7. QR code generated using SVG, this is a custom QR code which is optimized for screens only.It can be scaled to n bits and N colour channels

D. Multiplexed Colored QR codes

The rational of multiplexing multiple colored QR codes is the same as the above. The demonstration of the code and results are shown in the attached pdf along with this pdf.

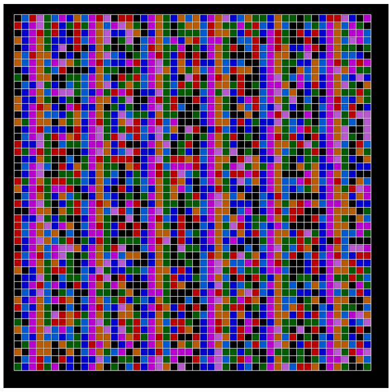

Fig. 8. Multiplexed image with R,G,B channels containing data

E. Degradation Function Design

This function is only for our theoretical results. we will first model some common degradation and see if our algorithm is able to detect the data at receiver end. The demonstration of the code and results are shown in the attached pdf along with this pdf.

F. Noise Addition Algorithm

We are adding Gaussian noise as that is a more probable model to be added when we do the experimental tests. This is because the screens have uniform noise. The demonstration of the code and results are shown in the attached pdf along with this pdf.

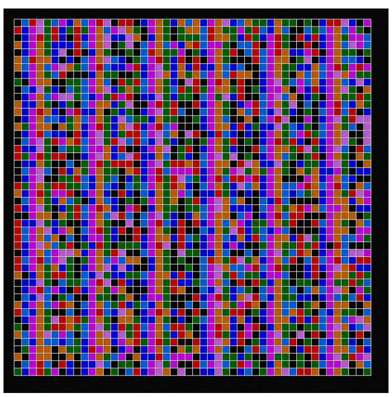

Fig. 9. Multiplexed image with noise added to it to simulate noise in real environment

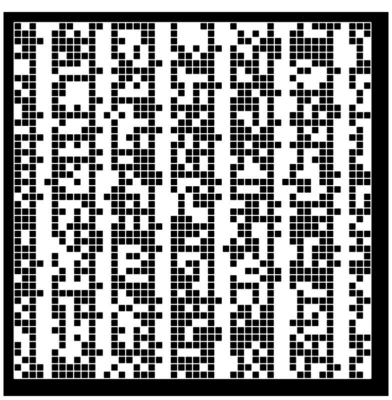

Fig. 10. Threshold to remove artifacts

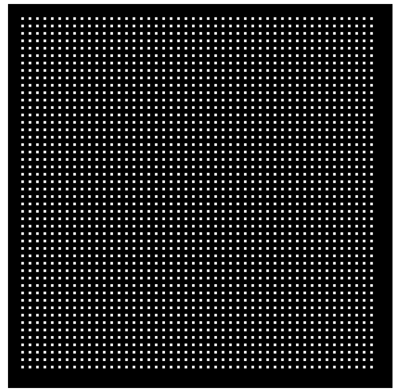

Fig. 11. Filter to remove all side unnecessary data.

G. Gaussian smoothing Algorithm

Results are shown in the attached pdf along with this pdf.

H. Otsu thresholding Algorithm

Otsu thresholding is performed after the process of Gaussian filtering.The demonstration of the code and results are shown in the attached pdf along with this pdf.

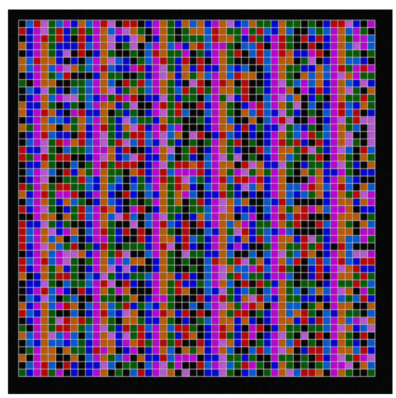

Fig. 12. removing noise using Gaussian filter

I. Edge detection Algorithm using laplacian

Use in the instance of translation of image due to the movement of camera while capturing the video. This will take care of any jitters or movement by isolating the grid and using it for image registration.The demonstration of the code and results are shown in the attached pdf along with this pdf.

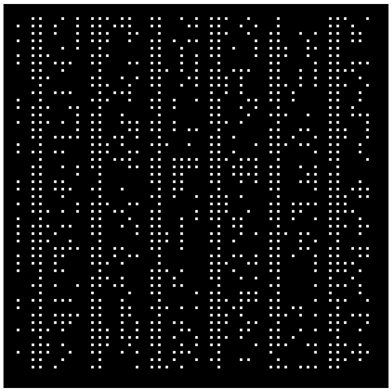

Fig. 13. data after filter applied

J. Algorithm for extracting data from QR code

To extract the binary information we are using a structuring element that works just like a morphological filter. It will remove all pixels from a particular box on the image of the QR code save the pixel values at the center. This is based on the assumption that all these other pixels close to the sides are noisy.
The grid size of each box used to represent a particular bit of data in the final bitstream is quite large hence when we apply the filtering through the structuring element, so it would ensure that the data we got is still correct due to the robustness of the data represented in the grid.
As we decrease the grid size the total area decreases hence our ability to do error correction would decrease but this would only matter in extreme noisy situations, at that point we can anyways keep the grid size as large as the one we have right now.
Next a hit or miss approach is utilized in the later stage for data extraction from the filtered image.
The demonstration of the code and results are shown in the attached pdf along with this pdf.

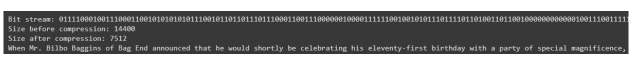

Fig. 14. data used for encoding

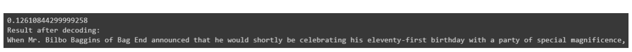

Fig. 15. Data recieved

K. Data Decompression Algorithm

The demonstration of the code and results are shown in the attached pdf along with this pdf.

L. Data Compression Algorithm (Hash compression)

The demonstration of the code and results are shown in the attached pdf along with this pdf.

V. Results and Analysis

To test out the time complexity, the pixels per box size of QR code was changed to 25, 50, and 75 which gave us the results shown in the figure below. The Graph below shows the time for different QR codes to be made. This will provide us with insight into how effective it will be when used for larger data sets.

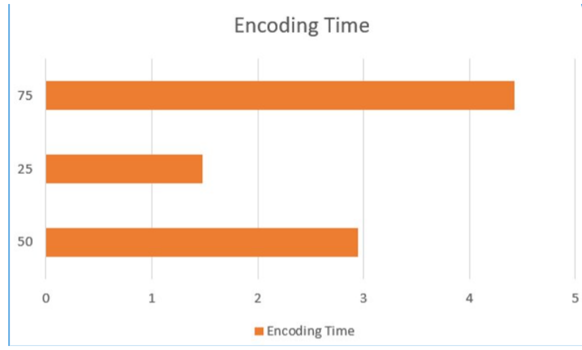

Fig. 16. The graph shows n which is the number bits the matrix contains nxn and Time in seconds

VI. Challenges and Difficulties

The path towards the completion wasn't smooth and rather we were faced with some issues from the start of the project till its completion.
One of the major issues was with the pixel ratio when we were generating pixels for the image boxes i.e for the process of converting our text to image.Therefore we had to formulate and design a separate algorithm to solve this issue which was both challenging and time consuming.
Another issue that arose was that just a difference of a single bit would mean that their will be errors while applying the compression and the decompression algorithm on our data.
Other than that we had to apply various algorithms throughout the span of the project such as Gaussian smoothing algorithms for noise reduction, different sharpening algorithms and compression algorithms etc as well as other pre-processing steps with regards to digital image processing. As such the learning curve for the project was quite high owing to the amount of prerequisite knowledge required.

VII. Applications/Case Studies

Because of the one-of-a-kind mechanisms that it employs, McKibben Pneumatic Artificial Muscles may be used for a broad range of applications in a wide number of robotics-related fields. A few applicatons are as follows:

A. Marketing and Advertising

Multicolored video QR codes can be used to deliver a more engaging and interactive brand experience to consumers. For example, a company could create a QR code that, when scanned, displays a video advertisement for a new product. This could be particularly effective for reaching younger audiences, who are often more receptive to digital marketing efforts.

B. Retail

In the retail industry, multicolored video QR codes could be used to provide customers with additional information about products in a store. For example, a customer could scan a QR code on a product's packaging to access detailed descriptions, pricing, and customer reviews. This could help to improve the shopping experience and encourage customers to make informed purchasing decisions.

C. Education

In educational settings, multicolored video QR codes could be used to deliver interactive lessons and presentations to students. For example, a teacher could create a QR code that, when scanned, displays a video lecture or tutorial on a particular subject. This could be particularly useful for remote learning situations, where students may not have access to in-person instruction.

D. Events

vent organizers could use multicolored video QR codes to provide attendees with information about the event, such as schedules, maps, and other useful details. For example, a QR code displayed at an event could be scanned to access a detailed schedule of sessions and activities, or to see a map of the event grounds. This could help to make the event experience more convenient and seamless for attendees.

E. Tourism

Tourist attractions and destinations could use multicolored video QR codes to provide visitors with information about the location, including historical background, cultural significance, and other points of interest. For example, a QR code displayed at a historical site could be scanned to access a video tour or interactive timeline of the location's history. This could enhance the visitor experience and encourage more in-depth exploration of the site.

F. Transportation

Transportation companies could use multicolored video QR codes to provide passengers with information about their travel itineraries, including flight or train schedules, gate numbers, and other important details. For example, a QR code displayed at an airport could be scanned to access a detailed flight itinerary, or to see real-time updates on a flight's status. This could help to make the travel experience more convenient and stress-free for passengers.

VIII. Conclusion and Future Work

In conclusion, multicolored video QR codes are a powerful tool that can be used in a variety of applications to deliver rich, interactive content and enhance the user experience. These codes have the potential to revolutionize the way that businesses, organizations, and individuals communicate and share information, and they offer numerous benefits over traditional QR codes. Some potential applications for multicolored video QR codes include marketing and advertising, retail, education, events, tourism, and transportation. By leveraging the capabilities of these codes, businesses and organizations can create more engaging and immersive experiences for their customers and users, and facilitate the exchange of information in a more efficient and convenient way.

References

[1] K. Hocaoğlu, A. Adar, Y. A. Arıkök, and V. Rodoplu, "Design of a Low-Cost Visible Light Communication (VLC) System for Music and Video Streaming," IEEE Xplore, Oct. 01, 2019.

[2] M. Abas, A. A. Yusof, N. Din, M. A. Azali, and K. Osman, "Colored QR Code: A Review," Journal of Engineering and Applied Sciences, vol. 15, no. 2, pp. 561-566, 2020.

[3] E. Melgar, J. L. Doña, and F. Marques, "Colored QR code," Optics Communications, vol. 285, no. 9, pp. 2081-2084, 2012.

[4] X. Yang, X. Xu, K. Deng, C. Loy, and K. Lau, "Compressive sensing based chromatic distortion correction for high-density colored QR codes," Optics Communications, vol. 407, pp. 77-84, 2018.

[5] G. Grillo, G. Russo, and F. Sorbello, "High-capacity two-dimensional colored QR code," Optics Communications, vol. 283, no. 23, pp. 4660-4666, 2010

[6] W. Li, Q. Lu, S. Yan, J. Tan, and X. Wang, "Color QR Code Based on Video QR Code," IEEE Access, vol. 7, pp. 123492-123500, 2019

[7] "QR Code Tutorial - Thonky.com," www.thonky.com. https://www.thonky.com/qr-code-tutorial/

[8] S. B. Wicker and V. K. Bhargava, Reed-Solomon Codes and Their Applications. John Wiley Sons, 1999.

[9] "Multicolored Video QR Code for Short Range Data Transmission," www.youtube.com. https://www.youtube.com/watch?v=Nk$_wilFkPfg$