INCREASING STORAGE CAPACITY OF QR CODES

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DECLARATION STATEMENT

I hereby declare that the research work reported in the dissertation entitled "INCREASING STORAGE CAPACITY OF QR CODES” in partial fulfilment of the requirement for the award of Degree for Master of Technology in Computer Science and Engineering at Lovely Professional University, Phagwara, Punjab is an authentic work carried out under supervision of my research supervisor Mr. Vikas Verma. I have not submitted this work elsewhere for any degree or diploma.

I understand that the work presented herewith is in direct compliance with Lovely Professional University’s Policy on plagiarism, intellectual property rights, and highest standards of moral and ethical conduct. Therefore, to the best of my knowledge, the content of this dissertation represents authentic and honest research effort conducted, in its entirety, by me. I am fully responsible for the contents of my dissertation work.

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SUPERVISOR'S CERTIFICATE

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LIST OF ABBREVIATIONS

1. **QRC:** Quick Response Code
2. **CQRC:** Coloured Quick Response Code
3. **SQRC:** Secured Quick Response Code
4. **HCC2D:** High Limit Shaded Two-Dimensional Code
5. **MUX:** Multiplexing
6. **DEMUX:** De-multiplexing
7. **ZXING:** Zebra Crossing
8. **ASCII:** American Standard Code for Information Interchange
9. **ECC:** Error Correction Codeword
10. **UPC:** Universal Product Code
11. **ECA:** Efficient Compression Algorithm
12. **ERP:** Enterprise Resource Planning

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ABSTRACT

With the rapid increase in mobile smart phone technology and its users; QR (Quick Response) codes also became popular. QR codes are widely used in our daily life from social media websites to cashless shopping wallets, ERP (Enterprise Resource Planning) software implementation to display advertising and digital marketing etc.

This research work's main objective was to solve the major issue of QR code i.e. limited storage capacity. Various techniques and methodologies are reviewed, which can used to increase data storage capacity of QR code and to secure the QR code based ecosystem.

This research report is divided into seven chapters. In first chapter introduced about basics of QR codes, its features and structure and then compared three different kinds of codes – barcode, QR code and CQR code. Further in this chapter, also mentioned about existing storage capacity of different QR codes and error correction levels. Then in second chapter, written about the review of literature into three parts – data storage enhancement techniques, information security of QR code and data compression techniques. In third chapter scope of the research is discussed in brief. Thereafter, in the fourth chapter clearly mentioned about the basic objective of this research study and discussed about different research methodologies which was used to achieve the objectives and aim of the research. Further in fifth chapter, all research results are discussed with the help of comparison tables and graphs. The achieved results are briefly mentioned in fifth chapter with the help of two factors – storage capacity and computational overhead of QR codes. Thereafter in last chapter summary and conclusions are discussed in brief.

This research work can be helpful for the society because QR codes have many real life applications. Nowadays these QR codes are playing very important role for cashless society and these are found very useful for effective implementation of demonetization step. The QR codes can be easily found on street vendor's counter for making payments via e-wallets. Further, these QR codes can also be very helpful for implementation of smart cities.

KEYWORDS

1) **Encoding:** Encoding is a step of processes, which is used to convert text data (numeric, alphanumeric, byte or kanji characters) into the form of QR Code. Generally, encoding process contains steps like – converting input data into the ASCII equivalents, converting ASCII values into the binary stream and then after performing masking, it produces the Quick Response code.

2) **Decoding:** Decoding is the reverse process of encoding, in which QR codes are scanned to convert back into the actual text data. It consists reverse steps to convert back QR code into text data; steps includes – unmasking the QR code, converting binary values into ASCII equivalent and getting back the actual text data from the ASCII values.

3) **Compression:** Compression techniques are used to remove noise or extra bits from the data in order to minimize the storage space requirements. There are different compression techniques available such as Huffman Coding, ZIP, RAR etc. Few of them are lossy in nature and a few are lossless compression techniques.

4) **Decompression:** Decompression is reverse of compression; in this technique compressed data is usually converted back into its original form by adding extra bits or pixels into it. If data was compressed using lossy compression technique than there is some loss of data bits which can't be recovered.

5) **Multiplexing:** Multiplexing is used to combine multiple QR codes into a single QR code. It is useful to save density or storage capacity because using multiplexing techniques we are combining multiple QR codes of same module size or version values into a single QR code.

6) **De-multiplexing:** It is reverse process of multiplexing, in which we detect and separate all the combined QR codes into single-single entities for decoding purpose.

CHAPTER 1
INTRODUCTION

Quick Response Code or QR Code is a two dimensional standardized identification. It is produced and trademarked by Denso Wave Fused, which is an auxiliary of driving car organization Toyota Incorporation of Japan. QR codes quickly turned out to be extremely famous in different ventures also as a result of its different elements like speedy checking, self harm resistance and expansive information stockpiling limit when contrasted with customary standardized tags.

QR codes have two stages – Encoding Stage and Interpreting or Decoding Stage. To start with first stage, information encoding or producing a QR code is a straightforward assignment; anybody can make QR codes utilizing portable based or electronic QR code generator applications. By utilizing QR code generator applications one can stow away or encode diverse kind of information, for example, content, numeric, bits, bytes, meta-data, alphanumeric and so forth. Subsequent to encoding the information, client can download the created QR code as picture and client can utilize it for assortment of purposes like putting QR codes on business cards, site, flyers, things and so forth.

Second stage, QR code disentangling or perusing a QR code is likewise exceptionally straightforward, anybody with QR scanner application in his advanced cell needs to point camera of his cell phone at the QR code. The QR code checking application will unravel the concealed information behind the QR code and after that the comparing installed move will make place, for example, opening a site page, sparing another contact into telephone, show the content or to form an email or instant message and so on.

QR codes are exceptionally well known these days on account of expanded utilization of cell phones. Its applications incorporate thing following in logistics industry, item distinguishing proof in retail locations, to make installments in cashless economy utilizing Paytm sort of applications, in promoting and showcasing industry by setting QR codes on various commercials, to share online networking profiles and so forth. QR codes can likewise be utilized as a part of keen urban communities for area following and distinguishing proof. Advance its applications can be discover in ERP (Enterprise Resource Planning) frameworks for different ventures like human resource, biotechnology, logistics and so on.

QR codes can be utilized for various purposes, for example, to include another contact in cell phone, to divert on a specific page, to make and send pre-composed messages and instant messages, to include another occasion into the schedule, to make a telephone approach the organization's free toll number, to show shrouded terms and conditions with an extra security strategy, to show item depiction and so forth.

QR codes go from adaptation 1 to variant 40. Every variant has diverse data stockpiling limit since they have distinctive number of modules or module design. Here number of modules means number of high contrast specks which detail the QR code. QR code variant 1 has 21*21 modules though form 40 has 177*177 modules in it [31].

1.1 Features of QR Code:

Conventional 1D tags or barcodes are proficient to store greatest of 20 digits around, while 2D standardized tags or QR codes are able for putting away hundred times more data. Along these lines, QR codes give high stockpiling limit then customary standardized tags.

Bar codes can store information just in one heading or direction, while QR codes can store information in both horizontal and vertical bearings. On account of its two dimensional stockpiling trademark QR code can store same measure of data in one tenth space of one-dimensional standardized identifications.

It is simpler and safe to utilize QR code, all things considered, circumstances where QR codes can get some soil or harm. QR codes accompanied in-fabricated mistake adjustment ability i.e. Reed-Solomon codes.

QR codes accompanied three positional discovery designs in its three corners, which helps in fast checking. A QR code can be perused from 360 degree situating, so there is no compelling reason to examine the QR codes from a specific heading. What's more, QR codes are clear in both online and additionally disconnected modes.

Another liven of QR code is that they bolster distinctive dialects, for example, English, Kanji, Kana and so on.

QR codes are accessible free of cost as Denso Wave discharged the patent into open area. So it's allowed to encode or unravel QR codes.

1.2 Structure of QR code:

Two dimensional standardized QR code is skilled to store information as framework. The QR codes can be made in forty unique forms from variant 1 to variant 40; every adaptation is having distinctive number of modules. Figure 1.1 demonstrates the structure of Speedy Reaction code. QR code is made out of various segments, for example, – version data, format data, information and error correction keys, alignment patterns and quiet zone [32].

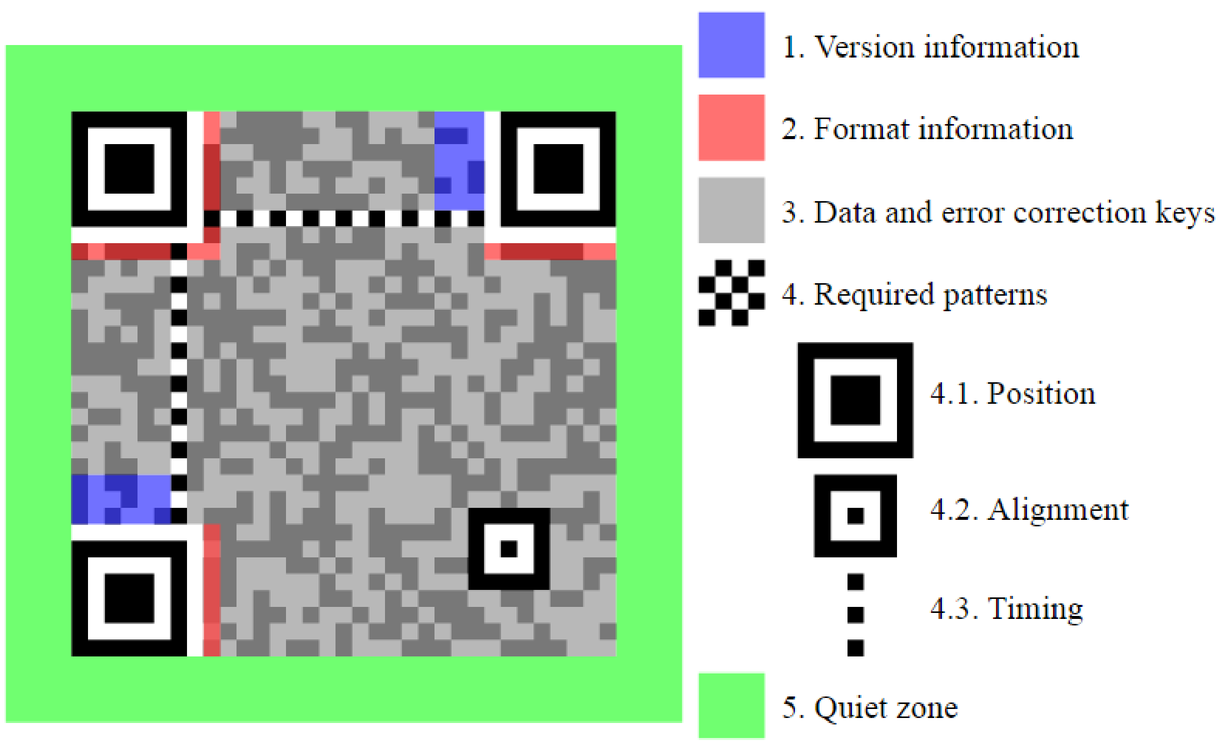

Figure 1.1 Structure of Quick Response (QR) Code [32]

Structure of Quick Response code contains -

1) Version Data of any QR codes is accessible in two rectangle boxes, which are set close position examples of right-upper corner and left-base corner. By examining these two boxes QR code decides the correct form number of QR code like rendition 1 or 2 and so on. It will then get data about aggregate number of modules present in the QR code as form 1 is having 21*21 modules and different variants have other module estimate.

2) Format Data about any QR code is put adjacent all the three position designs. Amid deciphering process, arrange data is the initial segment to be decoded. This segment of Quick Response code acquires information about blunder rectification and veil code. It is utilized to figure out which blunder adjustment level and which veil example is utilized to make a specific QR code. There are in all out 28 conceivable configuration data string as in Speedy Reaction codes we have four diverse mistake amendment levels (L-Level, M-Level, Q-Level and H-Level) and there are seven conceivable cover designs when all is said in done.

3) The dark cells of Speedy Reaction code speak to the Information and Mistake Rectification Keys. It contains real information put away in QR code and blunder adjustment codeword in view of Reed-Solomon calculation. Amid the encoding procedure of QR code first information is set in these dark cells and after that mistake redress codeword are put away.

4) Required Examples are otherwise called Work Designs, who are capable to give the correct position and auxiliary state of Brisk Reaction code to the QR code scanner.

5) Finder Example or Position Design makes QR codes speedy to react from any heading. It makes the QR code omni-directional; on account of this QR codes can be filtered in every one of the bearings (360º). These Position Examples are situated in three corners of the QR codes, left-upper corner, right-upper corner and the left-base corner.

6) Alignment Examples to dealing with and amending the twists in the QR codes. It is presented with the dispatch of form 2 of the QR codes and number of arrangement examples is expanded in the higher renditions of it. For remedy of twists scanner needs to recognize the focal directions of the arrangement designs. So for simpler discovery of

focal facilitated, a dark speck is set in the center part of it. Arrangement examples are extremely successful to remedy non-direct mutilations.

7) Timing Examples are set as option high contrast spots between discoverer designs. It is utilized for finding the code and revising the focal organize in circumstances when image is mutilated.

8) Quiet Zone is useful for perusing the QR codes. It is a sort of clear space encompassing outside the genuine QR code which indicates end of information of encoding.

1.3 Comparison of Barcode and QR Code:

Standardized tag as appeared in Figure 1.2 is a one-dimensional information portrayal strategy. It can speak to 10 to 20 digits of information in numeric and alpha-numeric shape. Standardized tags don't stores information inside it rather it speaks to the "key" to a record in a database. The record of a specific database additionally contains the data. Standardized tags turned out to be extremely prominent in shopping centers to store data about any item for simple charging and stock administration, assist its application can likewise be found in co-ordinations and warehousing industry too.

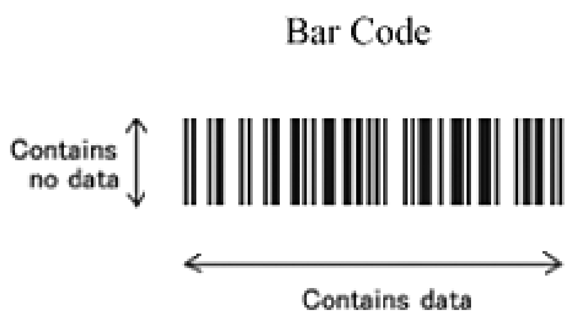

Figure 1.2 One Dimensional Bar Code

QR code is a two-dimensional information encoding strategy. QR code variant 40 can put away to 7089 numeric digits or 2496 alpha-numeric digits or 1817 Kanji digits and so on. QR codes have forty unique forms every variant has its own information stockpiling limit according to its module measure. It has four information rectification levels – L, M, Q and H for soil and harm resistance. The benefit of QR code over the scanner tag is that it can store more data, which can be perused precisely and effectively if there should arise an occurrence of some harm or soil also. QR code is appeared here in Figure 1.3.

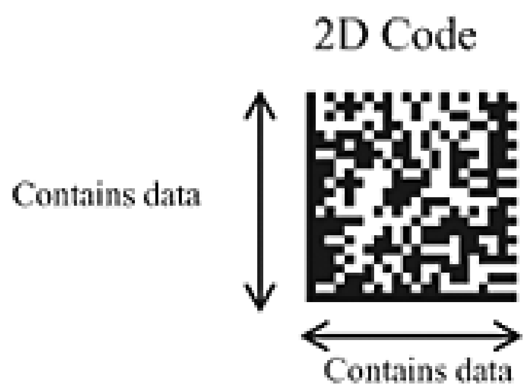

Figure 1.3 Two Dimensional Quick Response (QR) Code

CQR codes truncated as Shading QR codes are created to expand the information stockpiling limit of the QR codes. Customary QR codes have two hues – high contrast, yet if there should arise an occurrence of Shading QR codes more hues are included into the QR codes. The outcome was expanded information stockpiling limit and self marking of QR codes with hues are utilized to show fundamental data about QR code before unraveling it. Organizations began putting its logo inside the QR codes to exhibit its image. Here for correlation, we are thinking about five hued QR code engineer by Max E. Vizcarra Melgar et. al with five diverse RGB hues – red, green, blue, high contrast and they utilized 49*49 module size of the QR code. Shading QR Code is appeared underneath in Figure 1.4.

Figure 1.4 Color QR Code [1]

Table 1.1 Comparisons between Barcode, QR Code and CQR Code

Features	Bar Code	QR Code	Color QR Code
Storage Capacity	10 to 20 digits	Upto 7089 numeric digits	Twice the capacity of traditional QR codes.
Dirt and Damage Resistance	Not Available (Scanning is not possible)	Available (Scanning is possible upto 30% damaged)	Available (Scanning is possible upto 30% damaged with hight quality cameras)
360º Scanning	Not Available (supports only horizontal scanning)	Available (supports 360º scanning)	Available (supports 360º scanning)
Language Supported	Numeric and Alphanumeric	Numeric, Alphanumeric, Kanji, Kana etc.	Numeric, Alphanumeric, Kanji, Kana etc.
Dimensions	One-Dimensional	Two-Dimensional	Two-Dimensional

1.4 Storage Capacity of QR Codes:

There are forty distinct forms of standard two dimensional QR codes. Every variant is distinctive on the premise of number of modules, its size and thickness. Every form of QR code has diverse capacity limit as indicated by blunder redress levels. As indicated by Reed-Solomon blunder redress calculation, there are four unique levels of soil and harm resistance – Low Level (L), Medium Level (M), Quartile Level (Q) and Abnormal state (H). Every one of these levels are additionally characterized in the following point of this part. What's more, number of modules means number of high contrast dabs which figure the QR code. Table 5.1 demonstrates the diverse forms of QR codes with its number of modules and information bits stockpiling limit in light of four levels of blunder adjustment.

1.5 Dirt & Damage Resistance of QR Codes:

Quick Response code utilizes Reed-Solomon mistake remedy calculation for earth and harm resistance of the codeword. Each codeword of QR code is 8 bits in length. There are four earth and harm resistance levels which are say in Table 1.2. In the substantial QR codes, each message is additionally separated into a few Reed–Solomon code squares. The Reed-Solomon blunder redress calculation helps in deciphering the harmed QR code with the assistance of its predefined adjustment levels – L, M, Q and H. It is a decent element of QR codes that they stay meaningful even after some harm. In this way, in this research we are centred on enhancing the information stockpiling limit of the QR code the fundamental test for me is to keep up its harm resistance highlights. Along these lines, in the wake of applying proposed calculation, the harm resistance quality won't endure in any way.

Table 1.2 Dirt and Damage Resistance Levels of QR Code

Dirt & Damage Resistance Level	Symbolic Constant	Capacity of Error Resistance
Low Level	L	7% codeword's can be restored.
Medium Level	M	15% codeword's can be restored.
Quartile Level	Q	25% codeword's can be restored.
High Level	H	30% codeword's can be restored.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Storage Capacity Enhancement Methods of QR Codes:

Mona M Umaria et.al centered in their examination work to upgrade data stockpiling limit of QR codes utilizing Compress pressure calculation and idea of multiplexing. The proposed display initially dissects the info information that whether it is content, bits, bytes, numeric or meta information alphanumeric. In the wake of investigating it changes over the information into proportionate ASCII esteem, and encourages the ASCII qualities are changed over into the double document. At that point specialists have connected pressure methods on the parallel records, for example, – Compress pressure and Huffman pressure. At that point the packed document is encoded into a QR code. Further to improve more information stockpiling limit and to give security to it, the scientists have multiplexed the 5 QR codes. They found that Compress pressure system give more stockpiling limit then Huffman pressure as 3 KB document after pressure move toward becoming 1 KB if there should arise an occurrence of Compress pressure connected and 1.2 KB in the event of Huffman pressure connected. By utilizing multiplexing they have accomplished five times more stockpiling upgrade [1].

Grillo et.al proposed High Limit Shaded 2-dimensional Code (HCC2D), which is a cutting edge 2D code with expanded storage room than customary 2D codes and it protects an indistinguishable level of strength and solid unwavering quality from of QR code. This HCC2D code is created without losing the similarity with unique Fast Reaction principles. In this examination they have executed two new applications – encoder and decoder utilizing librencode and zxing library individually. Encode application can be utilized for creating or printing the HCC2D codes and the decoder application can be utilized for perusing or filtering the HCC2D codes [2].

Max E. Vizcara Melgar et.al acquainted another path with store and transmits information utilizing Shaded Fast Reaction (CQR) code structure. They have utilized five unique hues (red, green, blue, high contrast) to make a QR code rather than conventional highly contrasting hues. In view of these five unique hues, they have multiplied the capacity limit of new hued QR code in correlation with conventional paired Snappy Reaction codes. In this exploration they have printed the shading QR code and afterward checked it utilizing a 3.2 super pixel advanced camera. They have utilized QR code form 8, which is having 49*49 modules, and they have spoken to every module utilizing one out of five conceivable hues utilizing 24-bit RGB shading plan. To give shading thresholding in the examining procedure they have decided on red, green, blue and white hues on the grounds that these hues have most extreme equiv-remove in RGB shading model [3].

Jen-Shiun Chiang et.al proposed an approach in view of visual skew to upgrade the data stockpiling limit in the Speedy Reaction codes. In this examination they have presented a high thickness QR code approach with numerous view plot, which can increment 1.5 times more stockpiling limit than conventional QR codes. Recently presented multi-see QR codes contain three QR codes in front-see, beat view and side-see. The front-see contains an ordinary QR code and the top-view and side-see have two skewed QR codes. Encoding begins with making three QR codes for the information. Typical QR code structure is utilized to figure front-see and to plan beat view and side-see; they have utilized relative change to create the skewed QR codes. Interpreting of multi-view QR code begins with filtering the position examples of the QR code. It utilizes the position examples of the front-see QR code as reference and known skewed points to compute best view and side-see position QR codes. At that point utilizing relative change calculation, the skewed QR codes are changed over once again into the typical QR codes. Utilizing this proposed component the specialists have enhanced the capacity limit of ordinary QR codes by 1.5 times [4].

Darunee Bunma et.al proposed a way to deal with increment the information stockpiling limit of QR codes utilizing expand reality (AR). The specialists have found that QR codes can encode more data that conventional markers utilized as a part of AR. In this exploration QR codes are utilized rather than AR markers so as to upgrade the information stockpiling limit. The emphasis was on pressure techniques additionally to expand the information stockpiling limit [5].

Kim Ho Yeap et.al proposed to first pack the info record and after that encode it as a QR code keeping in mind the end goal to build the information stockpiling limit. The specialists have utilized RLE calculation curtailed as Run Length Encoding calculation for information pressure. RLE is a picture preparing calculation, which is straightforward and simple to utilize. Utilizing this calculation long rehashing string can be lessened into just 2 bytes, first byte referred to as run-consider and second run-esteem. Run-tally speaks to number of redundancies of same character and run-esteem speaks to the real information or estimation of the character. In the encoding procedure, initial step is filtering the record and changing over the content or sound or picture document into the parallel frame. This change permits putting away media documents in the QR code also. Subsequent to changing over it into double shape, specialist have connected RLE pressure calculation and afterward at last encoded the resultant into the QR code. A similar turn around process is actualized for interpreting of the QR codes. To start with output QR codes then disentangle it to get run-number and run-esteem data. At that point apply RLE decompression calculation to get back the double document lastly the information can be recovered once more from the twofold record. This exploration have produced the QR codes for picture and voice documents and expanded the capacity limit of the QR codes also [6].

P.S. Andre et.al presented the idea of shading multiplexing of the QR codes which prompts expanded capacity limit. The scientists have proposed to utilize higher request shading multiplexing plan. Rather than coding the data in highly contrasting specks, they have utilized added substance shading model as CMY. This procedure comes about into three times more stockpiling limit than customary monochromatic QR codes. By utilizing this approach QR codes is having eight unique hues – white, dark, cyan, fuchsia, yellow, red, green and blue. At that point complex high-arrange shading multiplexing method is connected on the code which additionally improves the capacity limit [7].

Nutchanad Taveerad et.al proposed another shading QR code strategy utilizing 16 distinct hues and the idea of hexadecimal values alongside parallel. In this exploration, information is encoded into the twofold stream and after that match of every four double values have been supplanted by a hexadecimal esteem. Furthermore, encourage HSV shading model is utilized to characterize sixteen unique hues as for each hexadecimal esteem. So in encoding process information is changed over into these sixteen shading spots rather to highly contrasting dabs utilized as a part of traditional QR codes. High contrast QR codes can just store 1 bit of data in module, though the proposed shading QR code can accumulate to 4 bits of data in every module. Along these lines, the information stockpiling limit is expanded utilizing this procedure. Disentangling procedure of shading QR code is especially like customary QR code, the main contrast here is that most importantly each shading spot is changed over into a hexadecimal esteem and after that the hexadecimal esteem is changed over once more into the twofold frame utilizing a table of hexadecimal to parallel transformation. Lastly the twofold record is decoded over into the first information put away. The specialists have built up an android based portable application and java based desktop application for encoding and translating of such 16 hued QR codes. Information stockpiling is expanded yet, translating procedure is not precise in contrast with high contrast QR codes as the disentangling exactness relies on natural conditions, for example, light, printer show shading and so forth [8].

Sibing Wang et.al proposed an approach of implanting stream utilizing which we can shroud a QR code behind a brilliant picture. These kind of QR codes with installing stream highlight can give more data about the QR code even before examining as by taking a gander at the QR code one can choose whether he needs to output it or not. It is constrained to data pass on as well as prompts increment information stockpiling limit in the QR codes. The looks into have utilized camera of iPhone 6 or more to sweep these QR codes and the QR examining application Wochacha, which depends on zxing library. There have proposed a four stage approach for implanted stream QR codes. To start with, they made a progression of inserted QR codes in dim cells. Second, they changed over these dark cells into shading codes. Third, they utilized a determination run for choosing legitimate QR code which is having most astounding disentangling capacities. Lastly, they settled on an implanted QR code. Inserted shading QR code gives more stockpiling limit and comfort to obtain data by taking a gander at the QR code also [9].

T. Iuliia et. al proposed new rich two level quick response (QR) code to implement private message sharing and document authentication. The proposed rich QR code have two levels for data storage and they have named is as 2LQR which stands for Two Level QR Code. It's two levels are named as public and private level as per their functioning as public level can be decoded from any of the decoding application for QR codes whereas private level requires a specific decoding application with specific input data. So, the 2LQR is helpful in situations like private message sharing, authentication, encryption key sharing etc. This research also results in increase of storage capacity of QR codes upto 28%. They have used textured pattern in this process using P & S process patterns. They have also compared this proposed model with other available models like – HCC2D Code, Multilevel 2D barcode, and Graphical code for authentication and QR code with hidden messages. They have further included three different types of error probability – mean, median and original for both pattern detection and the digital decoding [10].

Nivedan Bhardwah et. al proposed a decoding algorithm for color QR code as a mobile application for color QR code scanning. They have considered RGB color model which stands for Red, Green, Blue colors and then they have developed a mobile application for scanning such color QR codes. They have used google's zxing library, which is available as open source on github for everyone. The same zxing library is used in my research work as well to generate multicolor QR code for increasing storage capacity of the QR codes. They have used different image processing techniques such as Luminance Increase, Color Thresholding, Binarisation etc. for proper and fast decoding of color QR codes. First of all they have applied Luminance Increase technique to increase pixel values of each color. In step two, they have applied Thresholding, in which they have replaced six different colors with the shades of black and white colors. In step three, Binarisation is applied to grayscale image to match lightning conditions. And then in next step they have applied Salt and Pepper refinement algorithm on 3*3 matrix window size. And finally after Localisation (Local Luminance Enhancement), decoding is performed using the mobile camera for scanning with the mobile scanning application. Basically, they have converted the optimum resolution of QR code images for better scanning purpose [11].

C. Faten, C. Maha, P. William and B. Chokri have proposed a Quick Response (QR) code based watermarking technique for tracing traitors. In this proposed research they have used finger-print embedding technique and the Quick Response code in the audio stream, which is extracted from some other sort of media release. In this research they have used two different tracing codes named as Tardos code and Boneh Shaw into the Quick Response code. This proposed system consists of various steps including – watermark preprocessing step, watermark embedding step, watermark detection step, descrambling step and finally the matching step. They have further evaluated their research work upon various criteria such as storage capacity of QR code, embedding time, tracing results, watermarking robustness and inaudibility. This research finally concludes that there is a scope of great amount of information storage into QR codes [12].

J. Gonzalo has proposed QR Images for optimized image embedding in Quick Response Codes. In this research they have proposed a new concept about Quick Response Images for embedding QR codes into the color pictures or images with the detection error's bounded probability. These QR images can be easily decoded using QR code scanning applications First they inserted a picture and calculated picture's luminance for RGB color component model and then the scanning process of QR images is completed by using three steps process in which includes – binarization, detection and decoding of Quick Response image's bit stream. They have further described about threshold calculation for binarization, mean block binarization method and then finally sampling grip and sampling error's probability. They have also worked upon different techniques such as halftoning technique, pixel selection, luminance modification and color optimization. The proposed technique is useful in beautifying the QR codes with using images and this technique is very popular nowadays as different brands are using QR codes and they are putting their logo behind the generate QR code for indicating the branding. This technique is also helpful for easily identifying the QR code's purpose by simply looking at it. For example facebook's messanger application is providing QR code to each of its user which is embedded with the profile picture of the particular user. So, other user can directly identify by simply looking at the QR code that the particular QR code belong to his friend A or friend B. So, these QR images are helpful in generating brand values and easy identification of QR code's purpose [13].

Luz M. Santaner et.al reviewed channel capacity analysis of two dimensional barcodes including QR code and CQR code-5 in this research paper. In this study they represented different channel capacity on encoding and decoding of Quick Response code and Color Quick Response Code, which is based upon five different colors. They have used mutual information theory to study the channel capacity and they have taken hypothesis assumption that QR code and CQR code input symbols are in sequential form which further gives output sequence. The output sequence of each channel is dependent upon conditional probability and input sequence of each symbol. This research shows that maximum storage capacity is 1 or 2 bits per module of the any type of two-dimensional bar code either QR code or Color QR code [14].

2.2 Information Security in QR Codes:

E. Mete et.al implemented a two factor authentication system with QR codes for web and mobile applications. They have designed and implemented an alternative two-factor identity authentication system by using QR codes. The implemented system can be more user friendly and practical than the existing one time password (OTP) system for two-factor based authentication. They have used C#, ASP.Net and JQuery to design this system. They have also conducted several accuracy, quality, usability and security test after developing the prototype application. This research work has opened an alternative approach for SMS based one time password two-factor authentication [15].

H. Vladimir et.al proposed image steganography with using QR codes and cryptography. They have embedded the secret message using QR code into image. They have used DWT (Discrete Wavelet Transformation) for embedding of QR code and AES (Advanced Encryption Standard) technique for cryptography. The result of their proposed system shows that PSNR of their proposed system achieves higher values as compared to earlier methods [16].

K. Katharina et.al have focused in their research work about QR code security – how secure and usable apps can protect users against malicious QR codes. According to them, attackers can create malicious QR codes and put if end user tries to decode these codes using their smart phone than they can get trapped. For example the malicious QR code may result into opening a web page which is not safe to use. They have mentioned that how malicious QR codes can be very dangerous for its end users. So, they have also proposed set of design guidelines to build secure, usable and privacy conserving QR apps [17].

K. Saranya et.al have discussed about modern applications of QR codes for security. The research work was focused on different security aspects handled by QR codes and further directs to secure data transportation using Secured Quick Response Codes (SQRC). The proposed SQRC have various real time applications such as vehicle identity and verification, secure information sharing using stereography [18].

N.V. Akhil et.al proposed QR code security using proxy re-encryption. As per researchers transmission of QR code images from source to destination may cause into malicious attacks as well and data may loss in the transmission process. The proposed proxy re-encryption process can help in such situations to prevent and avoid these malicious attacks during QR code transportation. The re-encryption method secure environment to store and transmit confidential data using QR codes [19].

B. Karthikeyan et.al implemented enhanced security in Steganography using encryption and quick response codes. At sender's side they took the plain text or message and then applied encryption on that message. After that they have converted the encrypted cipher message into the

QR code. Further, the researchers have performed scrambling on the QR code and then hide the MSB bits of scrambled image into LSB bits of cover image; and finally get stego-image. This proposed system is useful for secure data communication [20].

L. Roger, Z. Jiazhen and K. Maxwell proposed a new framework for redesigning Quick Response code eco-system with more improved mobile security. Initially they have illustrated a lifecycle of Quick Response code which follows steps as generating or encoding of QR code, distribution of QR codes, reading or decoding of QR codes, triggering an action and finally expiration or decomposition of Quick Response codes. In QR code encoding phase, they have used hashing and encryption to generate a secured QR code which contains validity date and signature as well. And at the decoding phase reverse process has been applied to get back the original text. This research work has increased the security of information stored into the QR code as proper encryption of data was performed and by using hashing they are checking the data integrity and applied validity date concept, which is further helpful in decomposition of the QR code [21].

V. Ramya and G. Gopinath have reviewed QR codes for Information Security. In this research they have also reviewed about different Steganography techniques like – substitution technique, transform domain technique, spread spectrum technique, statistical technique, distortion technique and cover generation techniques. They have also discussed about the basic structure of QR code which include various parts such as – finder patterns, alignment patterns, timing patterns, quit zone and data area. Further, researchers have also focused upon information hiding used behind pixel values on QR codes, they have even talked about cover QR code concept. Cover QR codes both grayscale and binary covers, can be used to cover the actual QR code for security reasons. Then they have compared the information hiding behind grayscale images and binary images and concluded that binary images have better quality of Steganography images than the other one i.e. grayscale images. They have depicted the result by using PSNR (Peak Signal to Noise Ratio), MSE (Mean Square Error), AD (Average Difference), MD (Maximum Difference) and NAE (Normalized Absolute Error) factors. According to their algorithm they start with getting the secret message and then proceed with getting cover QR code image. After that they check for the condition that whether the given cover QR image is in binary format or not. If it is in binary format then they performed binarization operation over it followed by matching pixel values and embedding the data into the chosen pixel [22].

2.3 Data Compression Techniques:

Manjeet Kaur and Er. Upasana Garg focused in their research to form a new text data compression technique after reviewing various existing data compression techniques. In this research paper they have classified data compression techniques into two parts – Lossy Data Compression and Lossless Data Compression. Lossy data compression is best suitable for multimedia data such as images, video, audio etc. because in lossy compression technique some part of data may be lost to compress the data. For example one can decrease the pixels quality of an image to compress it. But, in lossless data compression, only unwanted data such as noise etc. are removed from data. This type of technique is useful to compress the text data [23].

Pooja Singh was focused on lossless data compression techniques and she has compared between different lossless data compression techniques in her research work. In the research work, she discussed about Shannon-Fano Coding and Huffman Coding. And then she compared between these two compression techniques based upon the parameters such as compression ratio (CR), compression factor (CF), decompression speed, memory space, compressed pattern matching and permits random access [24].

Amandeep Singh Sidhu and Er. Meenakshi Garg worked together for research paper on text data compression algorithm using hybrid approach. They have proposed Improved Dynamic Bit Reduction algorithm, which works in two phases for data compression. In first phase data is compressed with the help of dynamic bit reduction technique and in second phase Huffman coding algorithm is used to compress the data. The proposed system show good compression results in terms of compression ratio and saving percentage as compared to existing system [25].

K. Ahmad and P. Riccardo have proposed a new approach Evolutionary Lossless Compression with GP-ZIP for lossless data compression. They have proposed a revolutionary model in which they have divided the input into fixed predefined length of chunks and then for each individual chunk it asks for best suitable generic compression (GP) algorithm which can minimize the maximum size of input file. They have included different transformation techniques and compression algorithms for this research. General compression algorithms included are – Boolean Minimization, Run Length Encoding (RLE), Unbounded Prediction by Partial Matching (UPPM), Arithmetic Coding (AC) and Lempel Zip Welch (LZW). Burrows Wheeler Transformation (BWT) and Move to Front (MTF) transformation techniques are used in this research. They have found that using the proposed approach there is substantial improvement in compression, especially for different type of heterogeneous files. But on the other hand they found that this approach is computationally more expensive than other existing approaches [26].

N. Udita has proposed another new technique for compression of text data. The researcher has compressed the text input data with the help of fixed symbol length coding techniques. In this research, they have introduced a new method which not used anywhere else before i.e. binary 11 pair method. And they have also used 4 digits alphabet representation with lowercase and uppercase letters. The research has concluded that ternary coding method is more suitable than Universal Product Code (UPC) method because more data can be embedded in lesser space using ternary coding method [27].

J. Amit and P. Ravindra have proposed a new text data compression algorithm named as Efficient Compression Algorithm (ECA). The proposed algorithm contains two steps process – making an intelligent dictionary and encoding the input data. They have considered two parameters to evaluate final results, parameters are – Bits Per Character (BPC) and Conversion Time in seconds. These parameters are then compared by three distinct cases with the developed algorithm, cases are – simple BWT, BWT with star encoding and BWT with proposed method [28].

Md. Rafiqul and S.A. Ehsan have proposed an enhanced scheme for lossless compression of short text input type for source constrained devices. The main objective was to develop a light weight compression scheme which takes less computational time requires lesser storage space. The key factor of this research is in the knowledge entry choosing criteria. The proposed algorithm overcomes computational time overhead and requires lesser memory space [29].

CHAPTER 3
RATIONALE AND SCOPE OF THE STUDY

QR code gives helpful approach to covering up and sharing data in the computerized age. They are generally utilized as a part of online networking systems, funds transfer, logistics, publicizing and numerous different fields. According to the expanding interest for the utilization of QR codes, as researcher we need to concentrate on different issues related with it and attempt to solve those. According to our writing audit we can characterize the two most basic issues with QR codes are – storage capacity and data security.

We have seen different approaches used to build the capacity limit according to the business request. Everyone wants to store more and more data in a little zone of QR code. Till the time we have seen improvement of shading QR codes utilizing 5 shading model and 16 distinctive shading models. Adding more hues to the QR code can build its stockpiling limit. In this exploration main concentration was on capacity limit improvement of QR codes by utilizing compression of information before encoding and after that we likewise attempt to add more hues with a specific end goal to build its stockpiling limit. Further consideration was on its self blunder amendment technique utilizing Reed-Solomon calculation.

Security of QR code is another real issue. All in all nobody can distinguish that whether the QR code is produced by bona fide organization or not by essentially looking on it. So as to defeat this issue, various researchers have attempted to insert organization logo or brand picture behind the QR code so that by taking a gander at QR code one can distinguish it. Advance our emphasis was on making QR codes with more stockpiling limit in less space with greater security to the data put away into it. We can likewise take a shot at putting away private data into QR codes utilizing open key encryption strategy and computerized marks to give data verification, classification and integrity.

Along these lines, extent of this research work is centered on one noteworthy issue of QR codes that is information storage capacity. A prototype has been developed by utilizing different techniques to fathom storage capacity issue.

CHAPTER 4
PRESENT WORK

4.1 Problem Formulation:

Selecting or defining a research problem is one of the most crucial and important step towards any research work. For me, meaning of a research problem is finding a gap between existing technology and making it more useful for the society by breaking down its limitations. By following simple steps to find-out that research gap; initially started with reading about any technology which gives interest in reading and understanding the concepts. Thereafter started searching for something which is new and which can be improved. After reading lots of articles, books, publications and research papers, I found that QR code is that one thing – which is new, which can be improved and which have lost of real life applications. So, afterwards narrowed down my study and then started reading only about Quick Response codes. By reading lots of research paper, discussed those with my dissertation mentor. And in open discussion, we found numerous problems associated with QR codes or let's say we found the gap between technologies used behind QR codes.

The most of the problems we found in QR codes are related to either its storage capacity or information security. So, first we have decided to focus on increasing storage capacity of QR code by developing new encoding and decoding algorithms. Now the problem was formulated for research work and that problem gives us title for this research work – "Increasing Storage Capacity of QR Codes".

Obviously we have followed few of the conditions in determining the research problem like – the problem should be attributed to someone individual or a group of people/systems, the problem must have different action plans to be resolved at least more than one action plan, there may be positive or negative outcome of any action plan etc. So, the problem which was formulated is basically targeting every digital system which is using QR codes either any Hospital ERP software or digital payment wallets or Aadhar cards. We realized that in digital economy QR codes are related to almost everyone in India or foreign.

4.2 Objectives of the Study:

The main objective of this research work is to enhance the data storage capacity of the QR codes. By achieving the research aim, we can visualize rapid increase in application domains of QR Codes, mostly for smart cities where one needs to store bulk amount of data. Nowadays India is experiencing demonetization step taken by Prime Minister of the country and QR codes can play major role for this step. They are also helpful for cashless society as many vendors have registered themselves with different e-wallet companies like paytm, freecharge etc. These e-wallet companies have installed QR codes at cash counter of such vendors. Any time when a customer wants to pay his bills, he only needs to scan that particular QR code. Afterwards the QR code decoder application start working by taking necessary action like opening payment gateway etc. But, still there is one major concern associated with the QR codes that is its limited storage capacity. So, objective of this research study focuses on solving this issue by applying proposed methodology.

Aim of this research work is to increase the data storage capacity of QR codes so that we can store more information into it. A prototype model has been developed using zxing open source library to increase storage capacity of QR codes. The developed prototype follows two algorithms named as Encoding Algorithm and Decoding Algorithm. These algorithms contain many advance techniques, which are helpful in achieving the research goal.

4.3 Research Methodology:

QR Codes can be easily generated using various web based applications and it can be read using any smart phone having Camera. So, encoding and decoding of the QR codes can be done using various free and open-source tools.

First, we developed a prototype for real-time application (android based) to generate and read the QR codes using Android Studio. There are some open libraries available i.e. qrlib in PHP and zxing in Java for android platform. Nowadays, usages of smart phones are increasing very rapidly and almost everyone carries his smart phone with him where ever he goes. That smart phone can be very helpful for the QR code based society. So mobile application is the best solution to generate, read and distribute QR code; and that too for specific android platform because android is dominating the mobile operating systems because of its largest user base. So, android based QR code encoding and decoding application can be most helpful to generate and read high storage color QR codes.

Data Storage - To enhance the data storage capacity of QR codes version 1 to version 40, different color QR code techniques have been used along with suitable lossless compression algorithms (Huffman, ZIP, Lempel-Ziv etc) and the concept of Multiplexing was also embedded into the algorithm. Further we have decreased the required storage space of by replacing each mask with the corresponding color likewise eight different masks can be represented by using a single color pixel dot. For confidentiality - SQRCs (Secured QR Codes) are already providing small level of stenography and cryptography but that is not sufficient for brute-force attacks as attacker will always have enough time for cryptanalysis.

All these algorithms of encoding and decoding Quick Response codes have been implemented in Java programming language using Android Studio as IDE tool and with the help of zxing open source library. Main aim or objective of this research work was to increase the storage capacity of existing black and white QR codes using various proposed techniques such as multi-color encoding, compression and multiplexing. The proposed algorithms replace existing masking method of standard QR codes with the defined eight different colors. In standard QR code, eight different masking patterns are used to represent different data bits, whereas in the newly proposed multi color QR code algorithm, we have replaced these masks with eight different colors.

4.3.1 Encoding Phase:

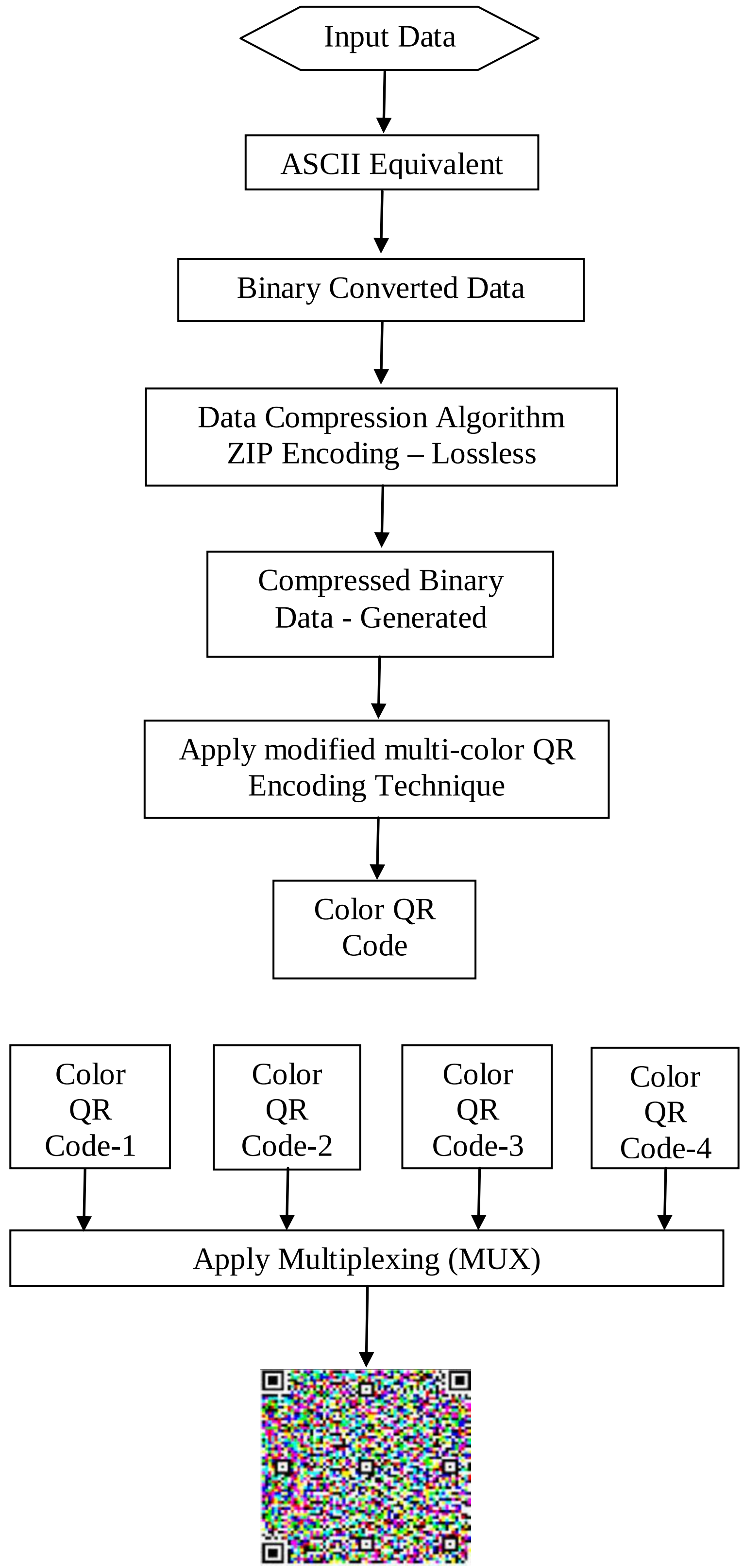

Figure 4.1 Flowchart of High Capacity Color QR Encoding

Algorithm for Encoding Process:

Step 1. Take Info Information (Content information to be encoded)

Step 2. Convert Info information into ASCII equal qualities

Step 3. Apply ASCII to Double Change

Step 4. Apply Information Pressure Method (Lossless Pressure – ZIP Encoding)

Step 5. Compressed Paired Information – Produced

Step 6. Apply adjusted shading QR Encoding Procedure (in view of zxing library) – RGB shading model based 8 distinctive blend of hues

Step 7. Take 4 distinctive shading QR codes

Step 8. Apply Multiplexing of every one of the 4 QR Codes (MUX)

Step 9. High Capacity shading QR Code

4.3.2 Decoding Phase:

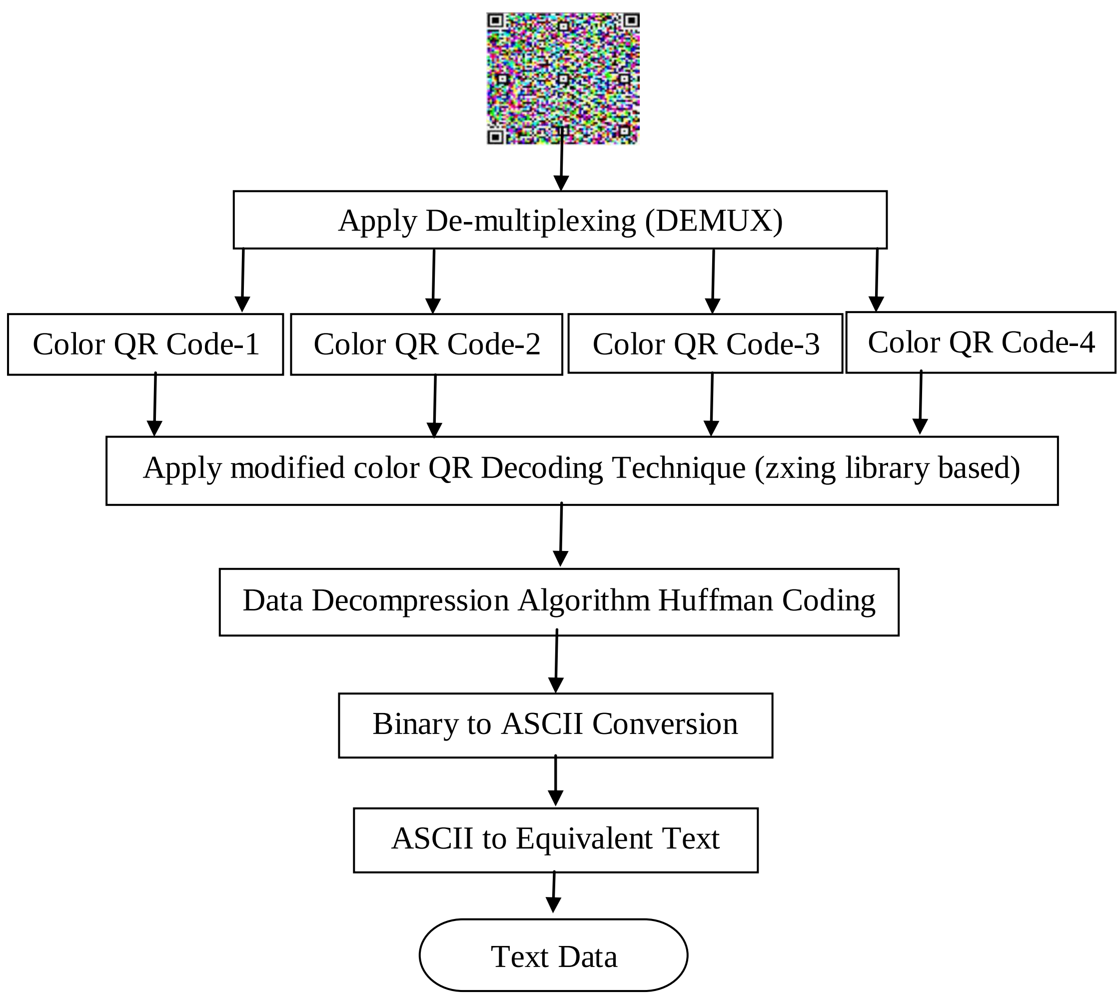

Figure 4.2 Flowchart of High Capacity Color QR Decoding

Algorithm for Decoding Phase:

Step 1. High Capacity QR Code

Step 2. Scan QR Code utilizing High Stockpiling QR Deciphering Application utilizing Android based advanced mobile phone

Step 3. Apply extraction/de-multiplexing (DEMUX)

Step 4. All 4 distinctive shading QR Codes – Produced

Step 5. Apply adjusted shading QR Deciphering Method (in view of zxing library) – Reed-Solomon for self harm resistance.

Step 6. Compressed Twofold Information – Created

Step 7. Apply Information Extraction Procedure (Compress Lossless Decompression method)

Step 8. Apply Twofold to ASCII Change

Step 9. Convert Two-fold values into its equal Content Information.

4.3.3 Selection of Required Tools:

The very next big challenge for any researcher is to equip his research work with the proper tools. While searching for the best available tool we looked for the tool which can help us to accomplish the task with desired results. Some general rules are followed for tools selection and some common pitfalls are avoided during the selection procedure. The tool selection procedure became little easier because of proper guidance by thesis mentor. Common avoided pitfalls are – using a tool which doesn’t include proper control structures to solve the formulated problem, using the tool to which I or my mentor have expertise to use even if the tool is not able to solve the defined problem, using the tool which itself is under development and having lots of error or using the tool which lacks in providing required functionality in order to solve the research problem. So, we analyzed the various available tools and after avoiding the common pitfalls, settled with working upon those tools. The selected tool is Android Studio and programming language as Java. I was new to the user interface of android, so I have given enough time to myself to better understand the android studio tool and its working procedure. Java is my all time favorite programming language and it suited best for the solution of the problem.

To solve the formulated problem or to simply test the hypothesis, we need to develop an application which can perform encoding and decoding of Quick Response codes, in simple language – an application was required which can be used to generate and scan the QR codes. So, here comes another problem about selection of tool that is which type of application it should be? Either web based application, desktop based application, mobile based application or wearable based application. After having enough discussion on this issue, I have settled with mobile application development which can encode and decode QR codes. The reason behind selection of mobile based application was simple that nowadays mobile devices are available with most of the people and another big reason was that every smart phone is equipped with a camera nowadays, which is helpful in the scanning process of QR codes. So no more additional hardware equipments will be required for scanning or decoding purpose. Let’s assume if I have opted to develop a desktop based application instead of mobile based app, in that case I need to arrange some extra hardware as well to perform decoding function.

After finalizing about development of mobile based application for encoding and decoding of QR codes, the next question was for which mobile platform? There are many different mobile platforms available such as Android, iOS, Windows etc. So, after reviewing few earlier researches and survey I have found that more than 80% of the mobile users and using Android platform followed by iOS and Windows. So, I have opted for Android based mobile application development for QR code encoding/decoding. Another reason for choosing Android is that it is open source platform and provides full flexibility to the programmers for developing applications and releasing those applications on play store.

Android uses Java programming language for development of apps and also includes XML, so Java comes naturally with the Android platform in my selection of tools. Further Java is feature rich programming language having enough functionality to implement my research work, so there was never any doubt about using Java as a backend programming language for development of QR code Android application.

There are many different IDE (Integrated Development Environment) available which provide support for development of android applications such as – Eclipse IDE, IntelliJ IDE, and Android Studio etc. I have opted for Android Studio because of various reasons such as it is exclusively built for development of Android applications, it always provides new updates and patches for new release of Android versions and it is directly the product of Android team. Along with these the GUI of Android Studio is simple and easy to learn.

So, I have equipped my research work with the tools like Android Studio as Integrated Development Environment, Java as backend programming language and Android platform for mobile based QR code application which can encode and decode the QR codes.

4.3.3 Multicolor Encoding & Decoding Technique:

The basic idea of this research moves around this step of multicolor encoding and decoding technique. As of now only black and white encoding and decoding techniques used to take place where white color was used as background and black dots are used to represent pixel dots, which hides data behind them using encoding process. Few people have tried to change these colors are well just to beautify the QR codes, let's say they have tried to change the background color from white to red or something else and even they have also tried to change foreground pixel color from black to blue or something else. By using such simple two color encoding technique, we can't increase the storage capacity of QR codes.

At encoding phase, user provides some text data to convert it into QR code and as per our encoding algorithm the plain text gets converted into the ASCII equivalent value and then we have converted ASCII value into the binary format. This binary value is compressed with lossless compression techniques i.e. ZIP compression and then we apply multi-color encoding on the compressed binary data to acquire a Multi-color QR code.

At decoding phase, we reverse the process as we need to convert the QR code into the plain text using our decoding algorithm. First we have applied de-multiplexing over the QR code to extract a single QR code from multiple multiplexed QR codes. After that we applied multicolor decoding technique and finally converted back those pixel values into the text format.

So, most important part is multicolor encoding and decoding which is an important step in both the phases. I have discussed about the structure of QR code in chapter 1, where we have seen every QR code contains multiple things like version information, format information, value of error correction level, different patterns and data masking.

There are eight predefined data masks available in Denso Wave's QR code structure. Basically every data mask represents three bit values in the binary format. So, the combination of different binary values are represented by different masks as shown below –

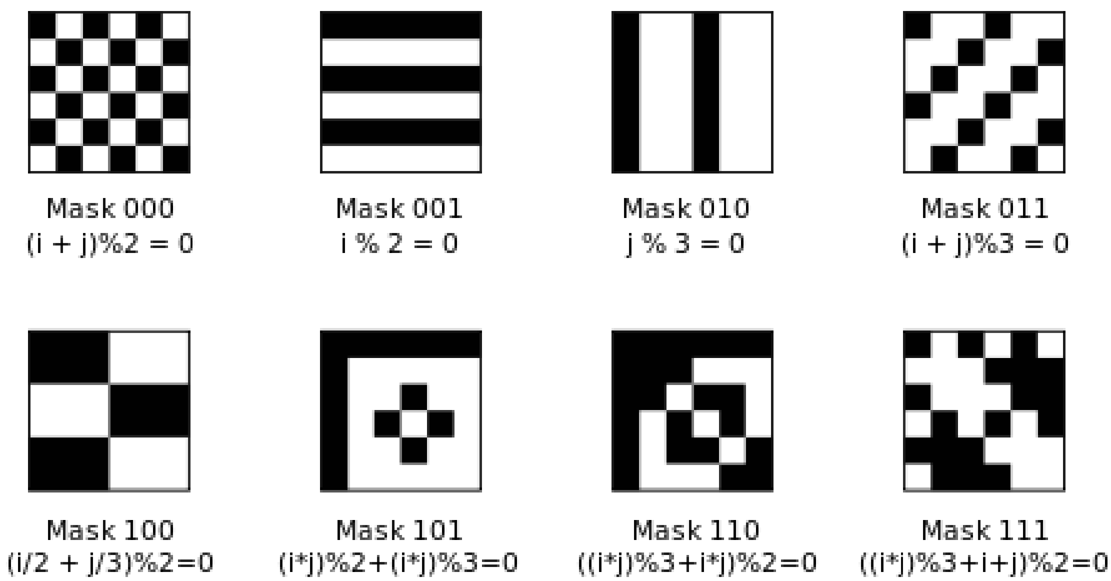

Figure 4.3 Different Masks in QR Code Encoding

We can see in Figure 4.3 that there are eight different masks available to represent three bit value, as $2^3 = 8$. In this research, I have allotted a different color pixel dot to each and every mask value and the default color information was stored into the block where version information gets stored. Therefore by default whenever we scan or decode a multi-color QR code, first of all it fetches version information along with the information of colors corresponding to masking patterns. So, it becomes easier for the decoder to read such information. Let's have a look at different colors with each mask of Quick Response code in the Table 4.1. I have used RGB color model which provides combination of three different colors Red, Green and Blue. And represented every color with the hex values, so I have turned the hex value on with ff for every bit on or bit 1 and I have turned off the hex value with 00 for every off bit or bit 0.

Using this multicolor technique increased storage capacity of QR codes but here was a big challenge for proper decoding or scanning of QR codes color hex values. I have mentioned all the different bit values along with their mask and respective color code in Table 4.1

Table 4.1 Hex values of RGB Color model corresponding to Masks

S.No.	Bit Value	Mask	Color (RGB)
1	000	Mask-1 (000)	#000000
2	001	Mask-2 (001)	#0000ff
3	010	Mask-3 (010)	#00ff00
4	011	Mask-4 (011)	#00ffff
5	100	Mask-5 (100)	#ff0000
6	101	Mask-6 (101)	#ff00ff
7	110	Mask-7 (110)	#ffff00
8	111	Mask-8 (111)	#ffffff

4.3.5 Data Compression & Decompression Technique:

Data Compression is a technique of reducing data size by removing unwanted elements and extra spaces. Data transmission of large files was always a pain, as it always causes the congestion in networks and takes lots of bandwidth for a long time period. So, data compression techniques became useful especially in such situations where we need to send large files via the network. One best example of such situation is emails. Different email providers have different size restrictions of email attachments, so one can only send emails with attachment size below the threshold. After evolution of Data Compression, it also becomes easier for the people to compress the file for reducing file sizes and send as attachment in the email. The same algorithm then applied at the receiver side to decompress the files. Hence storing and transmitting large files became easier with the help of compression techniques.

Different researchers have summarized the data compression technique into two different categories - Lossy Data Compression and Lossless Data Compression.

Lossy Data Compression is a technique in which recovered data after decompression may not be the same as it was before the compression; some part of data may loss in the compression process. This technique is mostly preferred for Digitally Sampled Analog Data or DSAD systems, which includes – image documents, illustrations, sound or features etc. As in the case of images lossy data compression technique reduces the pixel size of the image to achieve compressed data.

Lossless Data Compression is a technique in which recovered data after decompression is the same as it was before the compression. This technique generally removes the unwanted spaces, gaps and fillers to achieve the compressed data. There is never any worry about losing any part of important data.

Therefore after reviewing different techniques of lossy data compression and lossless data compressions such as ZIP compression, RAR compression, Huffman Coding compression, Arithmetic compression etc. and after proper analysis of their results, I have opted for ZIP compression technique to compress data input because it is lossless compression technique and it provides maximum compression over other available techniques.

4.3.6 Multiplexing & De-multiplexing Technique:

Multiplexing techniques contains set of rules that allows multiple objects to reside in a single block. In terms of networking, it is technique which allows multiple signal transmission via a single data link. In general, multiplexing is a method which can be used to combine multiple QR codes into a single QR code. De-multiplexing is a reverse process of multiplexing, as it is used to extract multiple objects from a single block like extraction of multiple QR codes which are multiplexed in a single QR code. So, the concept of multiplexing and de-multiplexing is very useful in situations where one needs to utilize maximum available space or in the data communication process.

Therefore in this research work, I have utilized the concept of multiplexing as well to combine multiple QR codes into a single QR code. This technique provides flexibility to store multiple QR codes of same module size into a single QR code. At the other hand, de-multiplexing at receiver side was used during the decoding process of QR codes which is helpful in extracting all different QR codes from a single multiplexed QR code.

So, proper use of multiplexing and de-multiplexing provided us an opportunity to save density of QR code space because of storing multiple QR codes in the module size of a single QR code. The challenge was at the decoding phase while de-multiplexing is dependent upon readability factor of the QR code scanner, camera quality in our case.

CHAPTER 5
RESULTS AND DISCUSSIONS

In my research work, I have developed an Android based mobile application to encode and decode multi-color QR codes or Ultra QR codes. I have implemented two different algorithms for generating multi-color QR codes (Encoding Algorithm) and for reading/scanning multi-color QR codes (Decoding Algorithm). The ultra QR code or multi-color QR code encoder and decoder applications are developed by using the zxing library in Android Studio. Zxing library is an open-source project in Java programming language which supports encoding and decoding of two dimensional barcodes.

Now turning to experimental results, I have performed some experimental tests using the developed algorithm. During the experiments, my main motive was to calculate data storage capacity enhancement, computational time overhead and camera quality or lightning effects required for proper decoding of multi-colored QR code. I have performed manual experiments to conclude the final results on different versions of QR codes including version 1 to version 40 for different levels of error correction including – L, M, Q and H ECC levels. The computational results for increase in storage capacity are shown in the Table 5.1; the results are depicted for alphanumeric type of input. The Table 5.1 also provides comparison between existing data storage capacity of QR codes and newly increased data storage capacity using multi-color QR encoding technique. After summarizing the overall results about storage capacity enhancement, I have noticed a pattern in storage capacity increment. I have compared all versions with different ECC levels and found that there is approximately 29% increment in data storage capacity for ECC level L of each version of QR code; and there is approximately 25% increment in data storage capacity for ECC level M of each version of QR code as compared to existing black and white QR code. Further, I have measured that there is approximately 20% and 14% increment in data storage capacity for ECC level Q and H consecutively. So, overall there is 14% to 29% increment in storage capacity of QR codes.

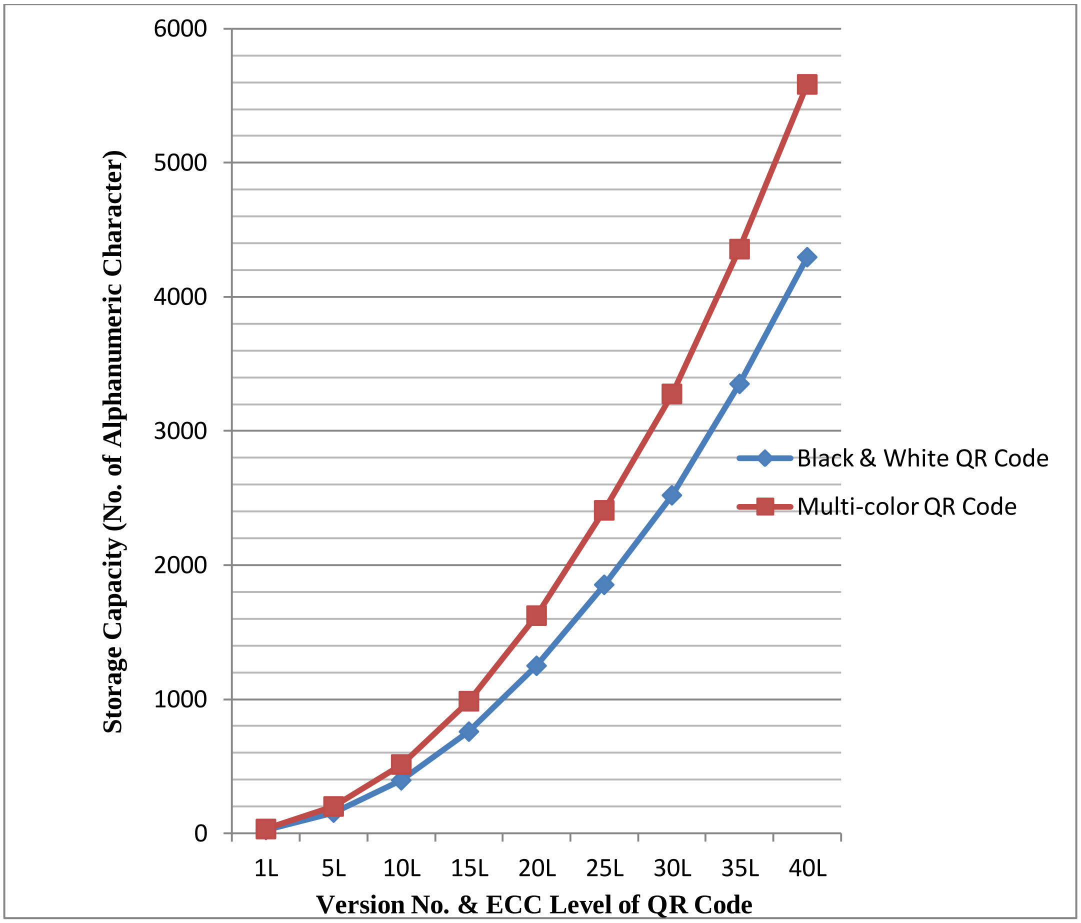

Figure 5.1 Increased Storage Capacity of Multicolor QR Code

Thereafter, I am addressing another factor that is computational overhead for multi-color QR codes. Computational overhead can be defined as average time required for decoding a multi-color Quick Response code during the scanning process. I have taken over hundreds of different QR images to depict the results of computational overhead factor. In Table 5.1, I have also compared the results of computational overhead experiment between standard black and white Quick Response code and multi-color Quick Response code. The results of computational overhead are shown in micro seconds scale. And I have noticed that there is uncertainty in results as the scanning process is completely dependent upon various other factors such as lightning conditions, camera quality and print quality of QR images. So decoding process is more time taking in case of multi-color QR code as compared to standard Quick Response codes. I have computed the computational overhead for version no 1, 5, 10, 20, 30 and 40 for all the ECC levels including – L, M, Q and H. I have also noticed that decoding become less painful in case if we are using 13 mega-pixel or better quality of camera in proper day lightning conditions.

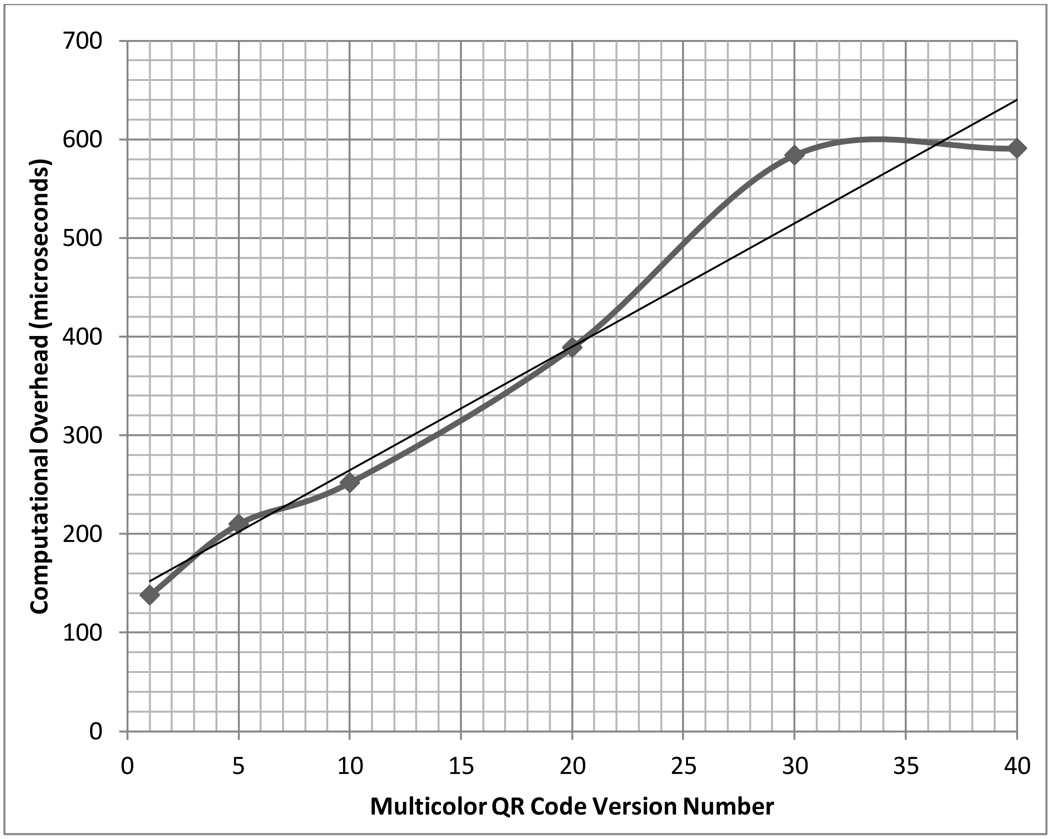

Figure 5.2 Relation between Computational Overhead and QR Version

The results for two different parameters – storage capacity and computational overhead are calculated manually. Table 5.2 shows comparison between standard QR code and multicolor QR code on the basis of both the parameters. The first parameter storage capacity is further depicted into Figure 5.1, which shows comparison between standard QR code and colored QR code using a graph. In this graph x-axis represents version information and y-axis shows storage capacity as number of alphanumeric characters; comparison is based upon nine different versions for ECC level L. The graph shows rapid increase in storage capacity of multicolor QR codes as compared to standard black and white QR codes. Thereafter, another parameter of computational overhead is depicted into Figure 5.2; two axis of graph are version number and computational overhead for x-axis and y-axis consecutively. The graph shows that computational overhead is also increased in multicolor QR codes as compared to standard bar code. The comparison was based upon five different versions of QR codes including – 1L, 5L, 10L, 20L, 30L and 40L. So by analyzing both the figures we can state that – storage capacity is increased in multicolor QR code on the cost of increase in computational overhead.

Let's take an example scenario to generate evaluate final results for multi color QR encoding algorithm. After taking input text of 30 alphanumeric characters "Lovely Professional University", encoded two different QR codes – one is by using standard QR encoding algorithm and another one is by using developed multicolor QR encoding algorithm. Results of encoding the give phrase are compared in Table 5.1; for standard black and white QR code phrase is encoded using version no 2 and error correction level M, whereas for multicolor Quick Response code, same phrase output is achieved in version 1 and error correction codeword level L. So, we can clearly see the improvement in results that multicolor QR code can store 30 alphanumeric characters into version 1 with ECC level L, whereas the same 30 alphanumeric characters are generated using standard QR code with version 2 and ECC level M.

Table 5.1 Results Comparison between QR Code and Multicolor QR Code

Parameter	**Standard QR Encoding**	**Multicolor QR Encoding**
Input Phrase (alphanumeric)	Lovely Professional University	Lovely Professional University
No. of Characters	30	30
Output QR Code		
Output Version No	Version – 2	Version – 1
Output ECC Level	ECC – M	ECC – L

In order to conclude the results in depth, below Table 5.2 shows the storage capacity in alphanumeric characters and computational overhead in micro-seconds for different versions and Error Correction Codeword (ECC) levels.

Table 5.2 Experimental Results of Storage Capacity & Computational Overhead

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (μsec)	
			Standard QR	Multicolor QR	QR	MCQR
1.	21 x 21	L	25	32	123	138
		M	20	25	123	137
		Q	16	19	129	139
		H	10	11	131	141
2.	25 x 25	L	47	61	-	-
		M	38	47	-	-
		Q	29	34	-	-
		H	20	23	-	-
3.	29 x 29	L	77	100	-	-
		M	61	76	-	-
		Q	47	56	-	-
		H	35	40	-	-
4.	33 x 33	L	114	148	-	-
		M	90	112	-	-
		Q	67	80	-	-
		H	50	57	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
5.	37 x 37	L	154	200	143	210
		M	122	152	151	212
		Q	87	104	163	214
		H	64	73	161	215
6.	41 x 41	L	195	253	-	-
		M	154	192	-	-
		Q	108	129	-	-
		H	84	96	-	-
7.	45 x 45	L	224	291	-	-
		M	178	222	-	-
		Q	125	150	-	-
		H	93	106	-	-
8.	49 x 49	L	279	362	-	-
		M	221	276	-	-
		Q	157	188	-	-
		H	122	140	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
9.	53 x 53	L	335	435	-	-
		M	262	327	-	-
		Q	189	226	-	-
		H	143	164	-	-
10.	57 x 57	L	395	513	176	252
		M	311	388	188	253
		Q	221	265	189	258
		H	174	200	190	259
11.	61 x 61	L	468	608	-	-
		M	366	457	-	-
		Q	259	310	-	-
		H	200	230	-	-
12.	65 x 65	L	535	695	-	-
		M	419	523	-	-
		Q	296	355	-	-
		H	227	261	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
13.	69 x 69	L	619	804	-	-
		M	483	603	-	-
		Q	352	422	-	-
		H	259	297	-	-
14.	73 x 73	L	667	867	-	-
		M	528	660	-	-
		Q	376	451	-	-
		H	283	325	-	-
15.	77 x 77	L	758	985	-	-
		M	600	750	-	-
		Q	426	511	-	-
		H	321	369	-	-
16.	81 x 81	L	854	1110	-	-
		M	656	820	-	-
		Q	470	564	-	-
		H	365	419	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
17.	85 x 85	L	938	1219	-	-
		M	734	917	-	-
		Q	531	637	-	-
		H	408	469	-	-
18.	89 x 89	L	1046	1359	-	-
		M	816	1020	-	-
		Q	574	688	-	-
		H	452	519	-	-
19.	93 x 93	L	1153	1498	-	-
		M	909	1136	-	-
		Q	644	772	-	-
		H	493	566	-	-
20.	97 x 97	L	1249	1623	240	389
		M	970	1212	253	391
		Q	702	842	250	393
		H	557	640	257	395

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
21.	101 x 101	L	1352	1757	-	-
		M	1035	1293	-	-
		Q	742	890	-	-
		H	587	675	-	-
22.	105 x 105	L	1460	1898	-	-
		M	1134	1417	-	-
		Q	823	987	-	-
		H	640	736	-	-
23.	109 x 109	L	1588	2064	-	-
		M	1248	1560	-	-
		Q	890	1068	-	-
		H	672	772	-	-
24.	113 x 113	L	1704	2215	-	-
		M	1326	1657	-	-
		Q	963	1155	-	--
		H	744	855	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
25.	117 x 117	L	1853	2408	-	-
		M	1451	1813	-	-
		Q	1041	1249	-	-
		H	779	895	-	-
26.	121 x 121	L	1990	2587	-	-
		M	1542	1927	-	-
		Q	1094	1312	-	-
		H	864	993	-	-
27.	125 x 125	L	2132	2771	-	-
		M	1637	2046	-	-
		Q	1172	1406	-	-
		H	910	1046	-	-
28.	129 x 129	L	2223	2889	-	-
		M	1732	2165	-	-
		Q	1263	1515	-	-
		H	958	1101	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	**Multicolor QR**	**QR**	**MCQR**
29.	133 x 133	L	2369	3079	-	-
		M	1839	2298	-	-
		Q	1322	1586	-	-
		H	1016	1168	-	-
30.	137 x 137	L	2520	3276	333	584
		M	1994	2592	350	588
		Q	1429	1714	347	591
		H	1080	1242	338	597
31.	141 x 141	L	2677	3480	-	-
		M	2113	2641	-	-
		Q	1499	1798	-	-
		H	1150	1322	-	-
32.	145 x 145	L	2840	3692	-	-
		M	2238	2797		-
		Q	1618	1941	-	-
		H	1226	1409	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
33.	149 x 149	L	3009	3911	-	-
		M	2369	2961	-	-
		Q	1700	2040	-	-
		H	1307	1503	-	-
34.	153 x 153	L	3183	4137	-	-
		M	2506	3132	-	-
		Q	1787	2144		-
		H	1394	1603	-	-
35.	157 x 157	L	3351	4356	-	-
		M	2632	3290	-	-
		Q	1867	2240	-	-
		H	1431	1645	-	-
36.	161 x 161	L	3537	4598	-	-
		M	2780	3475	-	-
		Q	1966	2359	-	-
		H	1530	1759	-	-

Version No.	Module Size	ECC Level	Storage Capacity (Alphanumeric)		Computational Overhead (MSEC.)	
			Standard QR	Multicolor QR	QR	MCQR
37.	165 x 165	L	3729	4847	-	-
		M	2894	3617	-	-
		Q	2071	2485	-	-
		H	1591	2068	-	-
38.	169 x 169	L	3927	5105	-	-
		M	3054	3817	-	-
		Q	2181	2617	-	-
		H	1658	1906	-	-
39.	173 x 173	L	4087	5313	-	-
		M	3220	4025	-	-
		Q	2298	2757	-	-
		H	1774	2040	-	-
40	177 x 177	L	4296	5584	430	591
		M	3391	4238	415	593
		Q	2420	2904	420	597
		H	1852	2129	373	601

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

Quick Response code gives helpful approach to covering up and sharing data in the computerized age. They are broadly utilized as a part of web-based social networking systems, digital wallets, promoting products in digital marketing, logistics and numerous different fields. According to the expanding interest for the utilization of QR codes, as scientists we have to concentrate on different issues related with it and attempt to determine it. According to our writing survey we can characterize the two most basic issues with QR codes are – stockpiling limit and data security.

We have seen different strategies use to expand the capacity limit according to the business request. Aim of our research work was to store more data in a little territory of QR code, which is achieved by using two different algorithms for encoding and decoding of multi-colored high capacity QR codes. Before this research work we have seen advancement of shading QR codes utilizing 5 shading model and 16 distinctive shading models. Adding more hues to the QR code increased its stockpiling limit. In future work our main focus will be upon decreasing computational overhead specially for the case of multiplexed QR codes and even multicolored as well. Along with that another future scope will be on capacity limit upgrade of QR codes for encoding different data types like images, audio, videos etc; and afterward additionally attempt to add more hues keeping in mind the end goal to expand its stockpiling limit. We will likewise give consideration on its self mistake adjustment strategy utilizing Reed-Solomon calculation.

Security of QR code is another significant issue. All in all nobody can recognize that whether the QR code is created by certified organization or not by basically looking on it. With a specific end goal to beat this issue, we will attempt to install organization logo or brand picture behind the QR code so that by taking a gander at QR code one can distinguish it. Promote our emphasis will be on making QR codes with more stockpiling limit in less space with greater security to the data put away into it. We can likewise chip away at putting away private data into QR codes utilizing open key encryption system and advanced marks to give data validation, classification and honesty.

Shading QR codes can store more data in little space as correlation with conventional QR codes. To store more information into QR code one can first pack the information and afterward produce the QR code. By performing pressure calculation and adding more hues to QR code, we can expand the data stockpiling limit. QR codes are broadly utilized these days; even QR codes are helping us to wind up plainly cashless economy. Different online wallets, for example, Paytm and so on are sending QR codes on the merchant's shop. Furthermore, anybody can undoubtedly filter the QR code utilizing his advanced cell to make installment towards his buy. Promote QR codes are utilized as a part of Aadhar Cards where they stores data around an individual resident of republic of India. QR codes can further be utilized as a part of savvy urban communities to effectively get to data about any item or to play out a specific activity through intelligence for instance by filtering a QR code one can book railroad stage ticket. In this way, there are differing uses of QR codes yet every application is additionally required to store more data into little region of QR code with data security too. A wide range of specialists have proposed different models to expand information stockpiling limit as examined in writing survey. For further upgrades we will concentrate on pressure, scrambling, and shading plans and so forth to expand its stockpiling limit. Alongside this for data security we will attempt to insert open key encryption and advanced marks on the QR code which can guarantee us about message validation and its trustworthiness.

In this way, future extent of this exploration is inconceivable as because of increment in QR code's ability; it will end up plainly less demanding for us to store, share and transmit more data utilizing QR codes. The eventual fate of QR code biological community is splendid as it is anything but difficult to create and simple to peruse utilizing any cell phone with camera. Encourage, I am hoping to enhance my work of research in up and coming years by encoding different sorts of information, for example, pictures, sound or even recordings too. QR codes are valuable in each circumstance in practically every industry.

REFERENCES

I. Research Papers

[1] M.M. Umaria and G.B. Jethava, *"Enhancing the data storage Capacity in QR code using Compression Algorithm and achieving security and Further data storage capacity improvement using Multiplexing,"* in International Conference on Computational Intelligence and Communication Networks, 2015, pp. 1094-1096.

[2] G. Antonio, L. Alessandro, Q. Marco and F.I. Giuseppe, *"High Capacity Colored Two Dimensional Codes,"* in Proceedings of the International Multiconference on Computer Science and Information Technology, 2010, pp. 709-716.

[3] Max E. Vizcarra Melgar, A. Zaghetto, B. Macchiavello and C. A. Anderson Nascimento, *"CQR Codes: Colored Quick-Response Codes,"* in IEEE Second International Conference on Consumer Electronics – Berlin, 2012.

[4] C. Jen-Shiun, L. Hsin-Ting, H. Chih-Hsien, W. Po-Han and H. Chi-Fang, *"High Density QR Code with Multi-View Scheme,"* in IEEE 17th International Symposium on Consumer Electronics (ISCE), 2013.

[5] B. Darunee and V. Sartid, *"Using Augment Reality to Increase Capacity in QR Code,"* in IEEE, 2014, pp. 440-443.

[6] Y. Kim Ho, C. Yuen Kiat, N. Humaira and T. Peh Chiong, *"A Simple Data Storage System Using QR Code,"* in IEEE, 2014.

[7] P.S. Andre and R.A.S. Ferreira, *"Colour multiplexing of quick-response (QR) codes,"* in Electronics Letters, vol. 50, November 2014, pp. 1828-1830.

[8] T. Nutchanad and V. Sartid, *"Development of Color QR Code for increasing capacity,"* in 11th International Conference on Signal-Image Technology & Internet-Based Systems, 2015, pp. 645-648.

[9] W. Sibing, Y. Tao, L. Jing, Y. Bowei and Z. Yanning, *"Does a QR Code Must Be Black and White?,"* in *ICOT*, 2015, pp. 161-164.

[10] T. Iuliia, P. William, D. Christophe, S. Oliver and G. Christian, *"Two level QR code for private message sharing and document authentication,"* in IEEE Transaction on Information Forensics and Security, 2015.

[11] B. Nivedan, K. Ritesh, V. Rupali, J. Alka and P. Anmol, *"Decoding Algorithm for color QR code: A mobile scanner application,"* in IEEE Fifth International Conference on Recent Trends in Information Technology, 2016.

[12] C. Faten, C. Maha, P. William and B. Chokri, *"A QR-Code Based Audio Watermarcking Technique for Tracing Traitors,"* in 23rd European Signal Processing Conference (EUSIPCO), 2015, pp. 51-55.

[13] J. Ganzalo, *"QR Image :Optimized Image Embedding in QR Codes ,"* in IEEE Transactions on Image Processing, 2013.

[14] Luz M. Santaner and Max E. Vizcarra, *"Channel Capacity Analysis of 2D Barcodes: QR Code and CQR Code-5,"* in IEEE COLCOM, 2016.

[15] E. Mete, C. Ece, S. Gizem and Z. Derya, *"A Two-factor Authentication System with QR Codes for Web and Mobile Applications,"* in Fifth International Conference on Emerging Security Technologies, 2014, pp. 105-112.

[16] H. Vladimir, B. Martin, K. Ondrej and L. Dusan, *"Image steganography with using QR code and cryptography,"* 26th Conference Radioelektronika, April 2016.

[17] K. Katharina, F. Peter, R. Thomas, K. Ioannis, U. Johanna and W. Edgar, *"QR Code Security – How secure and usable apps can protect users against Malicious QR codes,"* in 10th International Conference on Availability, Reliability and Security, 2015, pp. 230-237.

[18] K. Saranya, R.S. Reminaa and S. Subhitsha, *"Modern Applications of QR Code for Security,"* in 2nd IEEE International Conference on Engineering and Technology (ICETECH), March 2016.

[19] N.V. Akhil, V. Athira and S.K. Deepa, *"QR Code Security using Proxy Re-encryption,"* in International Conference on Circuit, Power and Computing Technologies (ICCPCT), 2016.

[20] B. Karthikeyan, C.K. Abhilash and G.S. Sudeep, *"Enhanced Security in Steganography using Encryption and Quick Response Code,"* in IEEE WISPNET Conference, 2016, pp. 2308-2312.

[21] L. Roger, Z. Jiazhen and K. Maxell, *"Redesigning QR Code Ecosystem with Improved Mobile Security,"* in IEEE 39th Annual International Computers, Software and Applications Conference, 2015, pp. 678-679.

[22] V. Ramya and G. Gopinath, *"Review on Quick Response Codes in the field of Information Security,"* in IEEE International Conference on Advances in Engineering and Technology (ICAET), 2014.

[23] Kaur Manjeet and Garg Upasana, *"A Review of Various Data Compression Techniques to form a New Technique for Text Data Compression,"* in Imperial Journal of Interdisciplinary Research (IJIR), Vol. 1, Issue 5, 2015.

[24] Singh Pooja, *"Lossless Data Compression Technique and Compression Between the Algorithms,"* in International Research Journal of Engineering and Technology (IRJET), Vol. 2, Issue 2, May 2015, pp. 383-386.

[25] Sidhu Amandeep Singh and Garg Meenakshi, *"Research Paper on Text Data Compression Algorithm using Hybrid Approach,"* in International Journal of Computer Science and Mobile Computing (IJCSMC), Vol. 3, Issue 12, December 2014, pp. 1-10.

[26] K. Ahmad and P. Riccardo, *"Evolutionary Lossless Compression with GP-ZIP,"* in IEEE Congress on Evolutionary Computations (CEC), 2008, pp. 2468-2472.

[27] N. Udita, *"A New Technique for Text Data Compression,"* in International Symposium on Computer, Consumer and Control, 2012, pp. 405-409.

[28] J. Amit and P. Ravindra, *"En Efficient Compression Algorithm (ECA) for Text Data,"* in International Conference on Signal Processing Systems, 2009, pp. 762-765.

[29] Md. Rafiqul and S.A. Ahsan, *"An Enhanced Scheme for Lossless Compression of Short Text for Resource Constrained Devices,"* in Proceedings of 14^{th} International Conference on Computer and Information Technology, December, 2011.

[30] G. Prabakaran, R. Bhavani and M. Ramesh, *"A Robust QR- Code Video Watermarking Scheme Based On SVD and DWT Composite Domain,"* in Proceedings of the International Conference on Pattern Recognition, Informatics and Mobile Engineering, February 2013, pp. 21-22.

II. Websites

[31] http://www.qrcode.com/en/about/version.html

[32] https://en.wikipedia.org/wiki/QR_code#/media/File:QR_Code_Structure_Example_3.svg

[33] https://pandazen.files.wordpress.com/2010/06/qrcode-http-pandazen-wordpress-com.jpg

APPENDICES

APPENDIX A: ZXING LIBRARY

Zxing stands for Zebra Crossing; is an open source Java library for encoding and decoding of Quick Response codes. The encoder part of the zxing library supports various formats such as – QR Code, EAN 8, EAN 13, UPC-A, Code 39, Code 128, Codebar, ITF, MSI, PDF 417, Aztec, Data Matrix etc. On the other hand, the zxing library also supports various formats for decoding as well, including – QR Code, UPC – A, UPC – E, EAN – 8, EAN – 13, Code 39, Code 93, Code 128, ITF, MSI, RSS 14, Aztec, PDF 417, Data Matrix etc.

So, we can see this library supports QR Code encoding and decoding part and it's available as open source Java project, that's why I have used this particular zxing library to implement my research work.

Supported Formats:

1D Product	1D Industrial	2D
UPC – A	CODE – 39	QR CODE
UPC – E	CODE – 93	DATA MATRIX
EAN – 8	CODE – 128	AZTEC (Beta)
EAN – 13	CODABAR	PDF 417 (Beta)

Active Components:

Modules	Description
Core	The core image decoding library and test code
Javase	JavaSE-specific client code
Android	Android client barcode scanner
Android Integration	Supports integration with barcode scanner via Intent
Android Core	Android related code shared among android, other apps
Zxing Org	The source behind zxing.org
Zxing.appspot.com	The source behind web based barcode generator zxing.appspot.com

APPENDIX B: ZIP COMPRESSION

B.1 Compression algorithm (deflate)

The deflation algorithm used by zip (also gzip and zlib) is a variation of LZ77 (Lempel-Ziv 1977, see reference below). It finds duplicated strings in the input data. The second occurrence of a string is replaced by a pointer to the previous string, in the form of a pair (distance, length). Distances are limited to 32K bytes, and lengths are limited to 258 bytes. When a string does not occur anywhere in the previous 32K bytes, it is emitted as a sequence of literal bytes. (In this description, `string' must be taken as an arbitrary sequence of bytes, and is not restricted to printable characters.)

Literals or match lengths are compressed with one Huffman tree, and match distances are compressed with another tree. The trees are stored in a compact form at the start of each block. The blocks can have any size (except that the compressed data for one block must fit in available memory). A block is terminated when deflate() determines that it would be useful to start another block with fresh trees. (This is somewhat similar to the behavior of LZW-based _compress_.)

Duplicated strings are found using a hash table. All input strings of length 3 are inserted in the hash table. A hash index is computed for the next 3 bytes. If the hash chain for this index is not empty, all strings in the chain are compared with the current input string, and the longest match is selected.

The hash chains are searched starting with the most recent strings, to favor small distances and thus take advantage of the Huffman encoding. The hash chains are singly linked. There are no deletions from the hash chains; the algorithm simply discards matches that are too old.

To avoid a worst-case situation, very long hash chains are arbitrarily truncated at a certain length, determined by a runtime option (level parameter of deflateInit). So deflate() does not always find the longest possible match but generally finds a match which is long enough.

deflate() also defers the selection of matches with a lazy evaluation mechanism. After a match of length N has been found, deflate() searches for a longer match at the next input byte. If a longer match is found, the previous match is truncated to a length of one (thus producing a single literal byte) and the process of lazy evaluation begins again. Otherwise, the original match is kept, and the next match search is attempted only N steps later.

The lazy match evaluation is also subject to a runtime parameter. If the current match is long enough, deflate() reduces the search for a longer match, thus speeding up the whole process. If compression ratio is more important than speed, deflate() attempts a complete second search even if the first match is already long enough.

The lazy match evaluation is not performed for the fastest compression modes (level parameter 1 to 3). For these fast modes, new strings are inserted in the hash table only when no match was found, or when the match is not too long. This degrades the compression ratio but saves time since there are both fewer insertions and fewer searches.

B.2 Decompression algorithm (inflate):

The real question is, given a Huffman tree, how to decode fast. The most important realization is that shorter codes are much more common than longer codes, so pay attention to decoding the short codes fast, and let the long codes take longer to decode.

inflate() sets up a first level table that covers some number of bits of input less than the length of longest code. It gets that many bits from the stream, and looks it up in the table. The table will tell if the next code is that many bits or less and how many, and if it is, it will tell the value, else it will point to the next level table for which inflate() grabs more bits and tries to decode a longer code.

How many bits to make the first lookup is a tradeoff between the time it takes to decode and the time it takes to build the table. If building the table took no time (and if you had infinite memory), then there would only be a first level table to cover all the way to the longest code. However, building the table ends up taking a lot longer for more bits since short codes are replicated many times in such a table. What inflate() does is simply to make the number of bits in the first table a variable, and set it for the maximum speed.