

## RESEARCH ARTICLE



# Bin Code: Encoding and Decoding of Picture Embedded Barcodes by Novel Intensity Bin

## OPEN ACCESS

**Received:** 21.05.2021

**Accepted:** 02.09.2021

**Published:** 03.10.2021

**S Ieswaria<sup>1\*</sup>, R Bhavani<sup>2</sup>, R Priya<sup>2</sup>**

**1** Research Scholar, Department of Computer Science & Engineering, Annamalai University, Chidambaram, India

**2** Professor, Department of Computer Science & Engineering, Annamalai University, Chidambaram, India

**Citation:** Ieswaria S, Bhavani R, Priya R (2021) Bin Code: Encoding and Decoding of Picture Embedded Barcodes by Novel Intensity Bin. Indian Journal of Science and Technology 14(32): 2616-2625. <https://doi.org/10.17485/IJST/v14i32.891>

\* **Corresponding author.**

[ieswaria@gmail.com](mailto:ieswaria@gmail.com)

**Funding:** None

**Competing Interests:** None

**Copyright:** © 2021 Ieswaria et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Published By Indian Society for Education and Environment ([iSee](https://www.indjst.org/))

**ISSN**

Print: 0974-6846

Electronic: 0974-5645

## Abstract

**Objectives:** To introduce a new algorithm for embedding pictures into barcodes, thereby facilitating the barcodes to hold the picture about its carrying information. This facilitates easier storage and faster retrieval, thereby avoiding manual errors and time consumption. **Methods:** The message to be embedded is encoded using Reed Solomon code and then embedded into the image by the proposed modulation method, finally generating a picture embedded barcode. **Findings:** The image quality and the information embedding capacity achieved by this method are proved to be higher than the previous works. **Novelty:** This study proposed an encoding/ decoding method for barcodes with pictures with the novel Intensity bins to generate a barcode with maximum visual quality.

**Keywords:** Barcodes; Encoding; Decoding; Modulation; Demodulation

## 1 Introduction

Data storage and retrieval have always been an active topic in almost every field. More and more research has been coming up continuously with groundbreaking innovations that proved creativity and the growth of the technological world. As human innovations increase, so does the data; thus, it demands efficiency in space, time, and much more performance metrics. In this fast-moving world, hundreds of users' data in institutions and organizations need to be processed, simplified under the users' unique ID (Identity). A student's ID in an academic institution is needed for attendance, mark allotments, assignments, fees updation, etc. An employee's ID in an organization is used for entry, automatic doors, job allotment, salary credit, etc.

Barcodes initially comprised bars and gaps of various lengths representing bits of information, usually about the object carrying the barcode. It started by printing barcodes on products at groceries as Universal Product Code for faster billing. And now every field has the use of barcodes for speedier access to data and avoid errors caused by manual intervention. Some of its applications are automatic rail car/car identification (Fastag), healthcare and hospital settings, steganography, and barcode tickets. The formulation or methodology that maps the barcode and the message stored in it is called the symbology. The idea of barcodes started with storing data as

one-dimensional barcodes along the horizontal direction, which came in various improvements in the symbologies such as Coda bar, Code 11, 25, 32, 39, 93, 128, EAN Code, Interleaved, Universal Product Code(UPC).

The next level of barcodes came into existence as an improvement from the previous works as two-dimensional barcodes, which allowed data storage along both directions such as Data Matrix, Maxi code, Dot code, PDF417, Quick Response (QR) code, Aztec code. As a next-level, these binary barcodes were given color allowing third-dimensional data storage. And the next level of advancement that has started research is embedding pictures into barcodes, thereby allowing barcodes to come out of the machine-readable structure and bridging the gap between humans and machines. Though barcodes allow automatic data retrieval and storage, human intervention has caused chaos. And barcodes in the form of the picture will enable a barcode to carry extra information on the picture of the detail it takes. For example, a barcode in the form of a person's face with the person's institutional ID.

Embedding pictures into barcodes has been done either pixel alteration or luminance and mostly portraits and standard color images like bitmap images. Iuliia Tkachenko et. al.<sup>(1)</sup> proposed a two-level QR code that facilitated the increase in data storage capacity and secrecy. It provided a layer of QR codes generally accessible by regular scanners and another hidden layer of QR code with specific binary textured patterns only accessible by a specific application. Tailing Yuan et. al.<sup>(2)</sup> proposed two-layered barcodes that facilitated the storage of two different messages on the same barcode structure by embedding them as two layers. These barcodes allowed reading one data from one angle and the other data from the other angle of the barcode generated by this method. Shih-Syun Lin et. al.<sup>(3)</sup> proposed a two-staged QR code that produces a synthesized QR code with better decidability and less visually enriched barcode as one stage and the second stage enhancing the visual appearance of the barcode with a 3% average error rate. Ya-Lin Lee and Wen-Hsiang Tsai<sup>(4)</sup> proposed a barcode by creating a pattern image with block substitution according to the message bitstream using pattern substitution and modulating the pattern image with the target image in its luminance produced barcodes in the form of pictures. The RS coding has been the standard algorithm used for error correction in barcodes traditionally. Changsheng Chen et. al.<sup>(5)</sup> proposed a barcode modulation/ demodulation method by pattern substitution in the luminance of the target image and fine corner detection of the barcode.

Gonzalo J. Garateguy et. al.<sup>(6)</sup> proposed a QR image where halftoning masks are used for producing optimized barcodes with nonlinear programming. Mingliang Xu et al<sup>(7)</sup> proposed a stylized aesthetic QR code that produced three-stage barcodes of baseline QR code, non-robust QR code, and robust QR code and produced an average 96% decoding success rate. NN. Ventsov and L.A. Podkolzina<sup>(8)</sup> proposed a one-dimensional barcode recognition model using the Artificial Neural Network and achieved an accuracy of 97.41%. Vidya Chandran and Ambika Sekhar<sup>(9)</sup> proposed picture embedded barcodes with Bose Chaudhuri Hocquenghem(BCH) code for encoding and decoding the message for better decidability and showed that for several instances, BCH code outperformed Reed Solomon(RS) code. A. Mittal<sup>(10)</sup> proposed embedding pictures into barcodes using circular modules altered in the luminance in accordance to center pixel to surrounding pixel and achieved a Structure Similarity Index Measure (SSIM) of 0.65 and Peak Signal-to-Noise Ratio (PSNR) of 11.29.

Pengjia Pang et. al<sup>(11)</sup> proposed a barcode called Codecube, which facilitated the storage capacity of normal QRcode thrice by encoding three different messages in the three channels and a border blur-aware method avoiding color blur. Karthik Dinesh and Gaurav Sharma<sup>(12)</sup> proposed a barcode generation method by generating three QR codes, embedding them in the R, G, and B channels, and finally producing a single RGB barcode concatenation of the three channels. This yielded data storage thrice and also giving a color barcode. Jia Ru Lee<sup>(13)</sup> introduced the Voice code, which facilitated the storage of voice input into barcodes. They converted the speech signal into a binary bitstream and generated a QR code for the speech bitstream. This paves the way for a new idea of embedding multimedia into barcodes which only followed traditionally storing alphanumeric and other texts.

Ye Li et. al<sup>(14)</sup> proposed a method to embed speech into a barcode using the MELP compression method to compress the speech data and then encode it into a barcode. This method achieved voice storage up to 39s at a compression rate of 600bps. H.R.Tizhoosh<sup>(15)</sup> proposed a feature-based image retrieval method where barcode annotations are used to retrieve medical images. This facilitated error-free and faster retrieval of data in the medical field. Y. van der Westhuizen and D. Chai<sup>(16)</sup> proposed a barcode that could send data using barcodes embedded in the video and allowing capturing data from the frames of video. The capturing device could read at the rate of 622 bytes/sec achieving 99% accuracy. Akshara M. Gaikwad and Kavita R. Singh<sup>(17)</sup> proposed a method for embedding pictures into barcodes using halftoning technique to select the modified pixels encoding data into the luminance of those modified pixels. Zhe Yang et. al<sup>(18)</sup> proposed a picture barcode that generated barcodes with coloured dot matrix and a better decoding scheme by enhancing the picture quality against the noises in the image. Ieswaria et al<sup>(19,20)</sup> proposed a modulation method to generate picture barcode by block pattern substitution method, which allowed 8 kb data to be encoded into the barcodes.

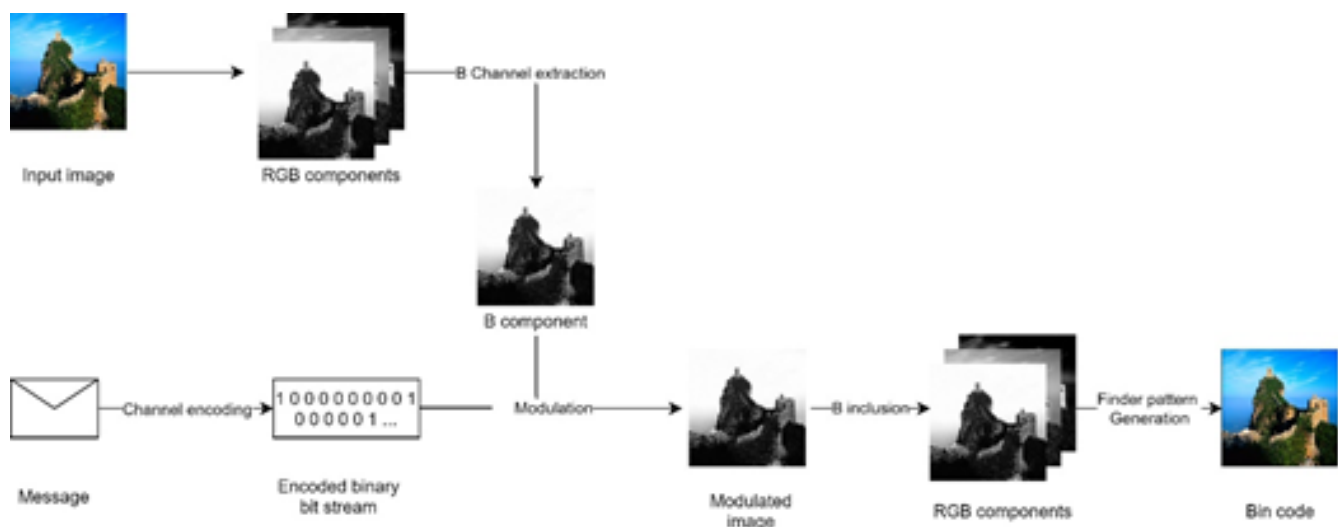
Various researches have been done in improving the barcode's efficiency in terms of space, time, and appearance. The modulation is the process of combining the message and the image according to picture-based barcodes and demodulation

is the process of extracting the message from the barcode image separating both. The modulation takes place by altering the pixels or luminance. Research works are being carried out in making the barcodes more efficient as the growing needs in the application demand better performance. The overall procedure of the proposed barcode modulation/ demodulation method is provided in section II. Section III provides the proposed method's experimental results and finally concludes the work in section IV.

## 2 Materials and Methods

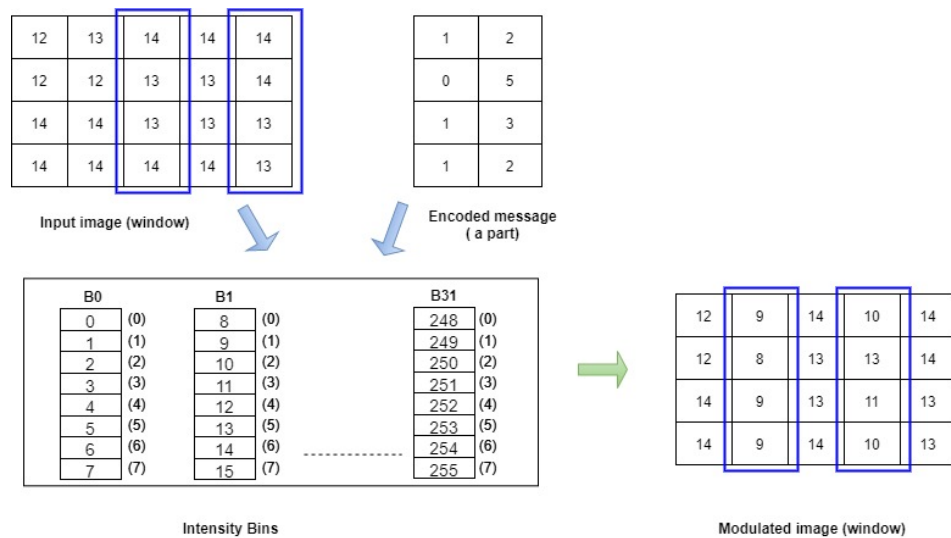
Aesthetic barcodes are an emerging field with active improvements in generating picture-embedded barcodes as efficient as possible. A novel encoding/ decoding method has been proposed to decrease visual distortion. The image is divided into blocks, and the message undergoes channel encoding to make it ready for modulation. According to the proposed method, the modulation occurs, and then the finder pattern is applied, generating the complete barcode. Finder pattern is a structure of image that usually is in black and white combinations allowing reading of barcodes- separating them from the rest of the area and letting the reader details about the barcode. The decoding takes place by removing the finder pattern, proposed demodulation, and then retrieving the message using channel decoding.

### 2.1 Encoding



**Fig 1.** Flow diagram for barcode encoding

Figure 1 shows the encoding procedure of barcode where the input image was taken is divided into equal-sized modules; a module collects the number of pixels which in barcode terminology is considered the pixels that hold each digit of the message. Here each pixel is taken to be a module to increase the embedding capacity of the barcode, and only alternative modules undergo modulation, where the rest of the pixels remain untouched to maintain the similarity between original and barcode images. The message goes through error correction using the RS channel encoder to protect the message. Reed Solomon code is a Channel coding algorithm that adds parity bits to the actual codeword/ data to control error while transmission. The message is now encoded into the barcode image using proposed Intensity bins for modulation and demodulation.



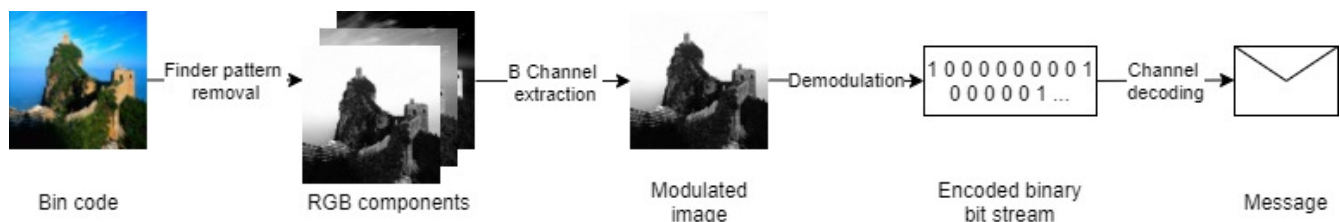
**Fig 2.** Proposed modulation technique with Intensity Bins

#### Algorithm 1- Encoding

Encode the message  $M$  and the Encoded Message matrix is  $E$   
 Select the B channel of the input image,  $I$   
 Select the pixels to be modified in  $I$   
 For  $a = E[i]$ ,  $i = 1$  to  $n(E)$   
 Check,  $I[i] \in \text{Intensity bin } IB_k$   
 Generate Barcode image,  $B[i] = IB_k[a]$   
 Apply finder pattern to the generated barcode image,  $B$

The proposed modulation technique introduces 32 Intensity bins, each holding eight intensity values from 0 to 255, as shown in Figure 2. The  $i^{\text{th}}$  element of the encoded message matrix is taken to be 'a', the bin that intensity of  $i^{\text{th}}$  module of input image falls is considered, and the  $a^{\text{th}}$  element of that bin is replaced in the encoded image. This takes place in the alternative modules (or pixels in this method) for every component of the encoded message matrix. For example, the  $i^{\text{th}}$  pixel value in an input image is 173, which is found to be in the intensity bin B21. The  $i^{\text{th}}$  element in the encoded message to be 2, the 2<sup>nd</sup> element of B21 is extracted. The extracted intensity value is replaced with the  $i^{\text{th}}$  module of the target barcode image generated. The encoded message finally undergoes Finder pattern generation, where the data matrix finder pattern is chosen to keep the encoded barcode image intact from any interrupt. The finder pattern consists of an L-shaped pattern along the left and bottom sides and dotted lines along the encoded image's top and right sides. The finder pattern of the data matrix is chosen to avoid interrupting the barcode area allowing more data storage capacity.

## 2.2 Decoding



**Fig 3.** Flow diagram for barcode decoding

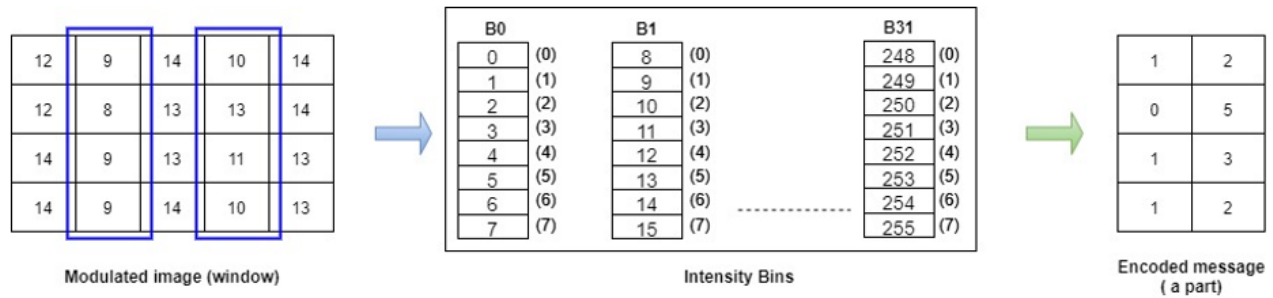


Fig 4. Proposed demodulation technique with Intensity Bins

Figure 3 shows the procedural flow of the decoding where the generated barcode is decoded by first removing the finder pattern regions of the barcode and then through the proposed demodulation procedure. Figure 4 shows the demodulation procedure that is processed according to the encoding method proposed. The  $i^{\text{th}}$  module of the barcode image is taken, and the intensity value is matched with the bins to find out which bin the intensity value falls. The position of the intensity value in the particular bin is taken to be the channel encoded message. The encoded message is then decoded using a Reed-Solomon decoder, by which the real message is obtained.

#### Algorithm 2. Decoding

Input: Barcode

Output: Message M

Remove the finder pattern and extract the encoded barcode image B

Select the blue channel of the image B

Select the modified pixels

For  $i=1$  to  $n(B)$

Check,  $B[i] \in \text{Intensity bin IBk}$

Check, If  $\text{IBk}[a] == B[i]$ ,  $a=0$  to  $7$

Generate Encoded message matrix,  $E[i] = a$

Decode the Encoded Message matrix E

and obtain message M






### 3 Results and Discussion

The input images taken for barcode generation are of two sets- (a) previous works (Picode) (b) Utrecht face database and maintained at a uniform size of  $512 \times 512$ . The previous works have considered specific images for comparison like the WWF logo, Lincoln portrait, Monalisa portrait, Hkust logo, great wall. The Utrecht database is a collection of face images of individuals from which 62 images were taken for this work. Each pixel of the image is assumed to be the module. Still, only alternative modules undergo the modulation where the encoded message is embedded, and the rest remain unaltered. This is done to avoid every pixel in the original image changing, and the human eye is sensitive to abrupt changes. The message (taken to be a person's ID number in this application) is encoded using an RS encoder for error correction. For this application, the ID is a 6-digit number which after channel encoding becomes 42 numbers thereby embedding 42-bit data into the barcode.






The encoded message consists of digits from 0-7. This being the primary motivation in dividing the intensity values into 32 bins, each comprising eight intensity values to represent the possibilities of digits in the encoded message. The encoded message is encoded into the image modules using the proposed modulation technique with Intensity bins. Thereby generating the proposed barcode image, which is then applied with the barcode finder pattern regions. The Data matrix's finder pattern is used here because this is followed in some of the previous works to avoid interrupting the barcode image data region and allowing better detection. The barcode at the receiver side first undergoes finder pattern removal, and then the alternate pixel values are taken into account. The pixel value is then checked for which bin it falls into, and the position of the intensity value in that particular bin is assumed to be the encoded message. The final original message is then obtained by passing the encoded

message into the RS decoder. [Table 1 ]

**Table 1.** Metrics evaluated for image set 1







Image	SSIM	PSNR	MS-SSIM
 <b>Lincoln</b>	0.99	80.23	0.99
 <b>Monalisa</b>	0.99	80.54	0.99
 <b>WWF</b> <b>WWE</b>	0.99	76.35	0.99
 <b>Hkust</b>	0.99	76.35	0.99
 <b>Wall</b>	0.99	78.04	0.99

**Table 2.** Comparison of previous works with proposed work using MS-SSIM

<b>Image</b>	<b>Halftone</b>	<b>QR code</b>	<b>Picode</b>	<b>Bin code (Proposed)</b>
 <b>Lincoln</b>	0.24	0.47	0.61	0.99
 <b>Monalisa</b>	0.16	0.31	0.63	0.99
 <b>WWF</b> <b>WWE</b>	0.43	0.46	0.61	0.99
 <b>Hkust</b>	0.38	0.44	0.63	0.99
 <b>Wall</b>	0.13	0.35	0.65	0.99



**Table 3.** Metrics evaluated for image set 2

<b>Image</b>	<b>SSIM</b>	<b>PSNR</b>	<b>MS-SSIM</b>
 <b>F4001</b>	0.99	80.43	0.99
 <b>F4002</b>	0.99	78.33	0.99
 <b>F4003</b>	0.85	10.91	0.98
 <b>M4001</b>	0.99	82.35	0.99
 <b>M4002</b>	0.99	79.73	0.99
 <b>M4003</b>	0.99	78.84	0.99



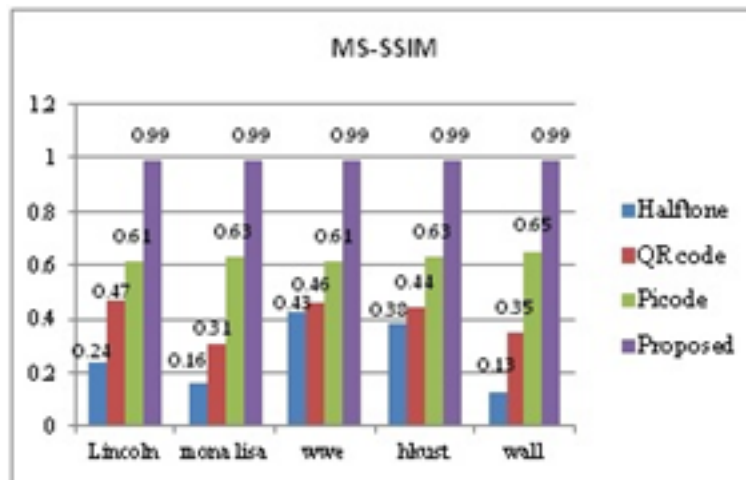


Fig 5. Comparison of previous works with proposed based on MS-SSIM

Table 1 shows the SSIM, PSNR, and MS-SSIM of the barcode generated by the proposed method for dataset 1. Table 2 and Figure 5 show the comparison of the previous works such as halfTone, QR code, PiCode, and proposed barcode based on MS-SSIM for dataset 1. The halfToneQR<sup>(21)</sup> produced monochrome barcodes by embedding the priority features from an image into the QR codes. Even though it attempted to safeguard the necessary features from the image, the barcode thus produced was a QR code that seemed like the embedded image with a limited embedding capacity of 440 bits. The QR image<sup>(6)</sup> was also an attempt to embed image features into the QR code. This used a halftoning mask to select the pixels to be modified and modulated the luminance of those pixels based on the mask and QR code. This work produced color QR codes better than the previous one yet had limitations in the barcode quality. PiCode<sup>(5)</sup> modified the luminance of the image and embedded pictures based on choosing bi-level pixels. This produced better image-based barcodes yet achieved a lower quality of the image with an embedding capacity of 512 bytes. The proposed work focuses on producing the best look-alike barcodes similar to the image being modulated. Table 3 gives the SSIM, PSNR, and MS-SSIM of the barcode encoded by the proposed method for dataset 2.

## 4 Conclusion

We proposed intensity bins-based modulation/ demodulation method which has been implemented with two data sets to emphasize the quality of the barcodes produced by this method with previous works and drew light upon the effect of the evolutionary work in barcodes for IDs. The proposed barcode method has generated barcodes with excellent visual quality with SSIM and MSSIM ranging from 0.98 to 0.99 for both datasets. It produced an average PSNR of 78.30 for dataset 1 and 67.53 for dataset 2. This barcode allows 16kb data storage, a very high quantity of data storage allowed by picture embedded barcodes so far, thus pushing the picture-embedded barcodes to a new level of improvement. The work has been done with 512\*512 images and can be done with other image sizes but the embedded capacity will vary. Capturing a real-time barcode image may contain various noises, so the issue can be overcome in the future.

## References

- 1) Tkachenko I, Puech W, Strauss O, Destruel C, Gaudin J, Guichard C. Rich QR Code for Multimedia Management Applications. In: Murino V, Puppo E, editors. International Conference on Image Analysis and Processing; vol. 2. 2015; p. 383–393. Available from: [https://www.researchgate.net/publication/281716734\\_Rich\\_QR\\_Code\\_for\\_Multimedia\\_Management\\_Applications](https://www.researchgate.net/publication/281716734_Rich_QR_Code_for_Multimedia_Management_Applications).
- 2) Yuan T, Wang Y, Xu K, Martin RR, Hu S. Two-Layer QR Codes. *IEEE Transactions on Image Processing*. 2019;28(9):4413–4428. doi:10.1109/TIP.2019.2908490.
- 3) Lin S, Hu M, Lee C, Lee T. Efficient QR Code Beautification With High Quality Visual Content. *IEEE Transactions on Multimedia*. 2015;17(9):1515–1524. doi:10.1109/TMM.2015.2437711.
- 4) Lee Y, Tsai W. A New Data Transfer Method via Signal-rich-art Code Images Captured by Mobile Devices. *IEEE Transactions on Circuits and Systems for Video Technology*. 2015;25(4):688–700. doi:10.1109/TCSVT.2014.2355693.
- 5) Chen C, Huang W, Zhou B, Liu C, Mow WH. PiCode: A New Picture-Embedding 2D Barcode. *IEEE Transactions on Image Processing*. 2016;25(8):3444–58. doi:10.1109/TIP.2016.2573592.
- 6) Garateguy GJ, Arce GR, Lau DL, Villarreal OP. QR Images : Optimized Image Embedding in QR Codes. *IEEE Transactions on Image Processing*. 2014;23(7):2842–2853. doi:10.1109/TIP.2014.2321501.

- 7) Xu M, Li Q, Member S, Niu J. ART-UP : A Novel Method for Generating Scanning-robust Aesthetic QR codes. *Journal of Latex Class Files*. 2015;14(8):1–14. Available from: <https://arxiv.org/abs/1803.02280>.
- 8) Ventsov NN, Podkolzina LA. Localization of Barcodes Using Artificial Neural Network. *IEEE East-West Design & Test Symposium*. 2018;p. 1–6. doi:10.1109/EWDTS.2018.852483.
- 9) Chandran V, Sekhar A. A secure and reliable channel error correction technique for picode. 2017. Available from: <https://www.semanticscholar.org/paper/A-secure-and-reliable-channel-error-correction-for-Chandran-Sekhar/354186477ac48a3a737fb857aa4c27b071495761>.
- 10) Mittal A. Generating visually appealing QR codes using colour image embedding. *The Imaging Science Journal*. 2017;65(1):1–13. Available from: <https://doi.org/10.1080/13682199.2016.1241941>.
- 11) Pang P, Wu J, Long C. CodeCube : A multi-layer color barcode for mobile social applications. vol. 29. 2017;p. 7713–7721. Available from: <https://ieeexplore.ieee.org/document/7978590>.
- 12) Dinesh K, Sharma G. Per-channel color barcodes for displays. 2016;p. 3992–3996. Available from: [https://www.researchgate.net/publication/307516215\\_Per-channel\\_color\\_barcodes\\_for\\_displays](https://www.researchgate.net/publication/307516215_Per-channel_color_barcodes_for_displays).
- 13) Lee JR, Ruan S, Lin CH. VoiceCode : A 2D Barcode System for Digital Audio Encoding. 2016;p. 1–2. Available from: <https://ieeexplore.ieee.org/document/7800472>.
- 14) Li Y, Ma X, Jiang J, Zhang P, Fan Y, Hao Q. A generation method for acoustic two-dimensional barcode. 2016;p. 303–307. Available from: <https://ieeexplore.ieee.org/document/7974585>.
- 15) Tizhoosh HR. Barcode Annotations For Medical Image retrieval : A Preliminary Investigation. 2015;p. 818–822. Available from: <https://ieeexplore.ieee.org/document/7350913?arnumber=7350913>.
- 16) Der WYV, Chai D. 3D dynamic barcode. *Image and vision processing and display technology*. 2018;54(17):1024–1026. Available from: <https://doi.org/10.1049/el.2017.4385>.
- 17) Gaikwad AM. Embedding QR code in color images using halftoning technique. vol. 2. 2015;p. 1–6. Available from: <https://ieeexplore.ieee.org/document/7193016>.
- 18) Yang Z, Bao Y, Luo C, Zhao X, Zhu S, Peng C. ARTcode: preserve art and code in any image. *UbiComp '16: Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. 2016;p. 904–915.
- 19) Ieswaria S, Bhavani R, Priya R. An Efficient Approach for Barcode Encoding / Decoding Using Pattern Substitution. *Electronic Systems and Intelligent Computing*. In: and others, editor. *Electronic Systems and Intelligent Computing*;vol. 686. 2020;p. 419–428. doi:10.1007/978-981-15-7031-5\_40.
- 20) Ieswaria S, Bhavani R, Priya R. Encoding and Decoding of Barcodes for Grayscale and color images. *Solid State Technology*. 2021;64(2):177–185. Available from: <https://solidstatetechnology.us/index.php/JSST/issue/view/52>.
- 21) Chu HK, Chang CS, Lee RR, Mitra NJ. Halftone QR codes. *ACM Transactions on Graphics*. 2013;32(6):1–8. Available from: [http://cg.cs.nthu.edu.tw/Projects/Recreational\\_Graphics/Halftone\\_QRCodes/](http://cg.cs.nthu.edu.tw/Projects/Recreational_Graphics/Halftone_QRCodes/).