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Enhanced Detection and Decoding of QR Code and Barcode using Machine Learning

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***Abstract*: This paper proposes a novel deep learning-based approach for the detection of QR codes and barcodes in images. The rapid adoption of QR codes and barcodes across various industries necessitates robust and accurate detection methods. Traditional methods often rely on handcrafted features and heuristics, leading to limited performance in complex scenarios. In contrast, our proposed approach leverages the power of deep learning to automatically learn discriminative features for precise detection. Extensive experiments demonstrate the superiority of our method in terms of detection accuracy and efficiency compared to state-of-the-art techniques. we propose a deep learning-based framework that addresses these challenges by leveraging the capabilities of convolutional neural networks (CNNs) for feature extraction and classification. Our approach involves two main stages: (1) detection of QR codes and barcodes within images, and (2) decoding the detected codes to extract the embedded information.**

***Keywords*: QR code, barcode, convolutional neural networks, computer vision, deep learning, opencv, numpy, pyzbar.**

1. Introduction

In recent times, there are enormous volume of goods are being produced and utilized on daily basis by the consumers. To have an effective control over the production, and distribution of goods, it is essential that each individual item is provided with an appropriate information or data to identify itself in a computer [1]-[3]. In order to serve the purpose, the Bar codes and QR Codes are widely used technique to convert each individual goods identity into a datum. Bar codes have taken over the world in making systematic order of goods/items [1]-[3]. If a product is packed to deliver in market, it has a Bar code which is used for all kinds of inventory/stocktaking work. The standard Bar code technology has significantly improved accuracy which leads to better management of inventory with low-cost implementation [1]-[6]. One can simply scan bar code and get all the relevant information that are stored in the database linked to it. 2D Bar code has received wide scope of consideration since the day it showed up for its preferences of huge stockpiling limit, high secrecy, solid protection from harm with several other features as well [5]-[14]. It became a significant research point in the field of pattern recognition and image processing.

Fig. 1. Examples of QR code symbols

Many researchers have investigated the domain of Bar code and QR code detection. Several methods have been reported in the literature. In 1932 Wallace Flint proposed a similar punch-card framework which was costly and lumbering like one produced for the 1890 U.S. Statistics. In 1952 Silver and Woodland form the main Bar code Reader for which the patent was granted. In 1967 Association of American Railroads starts utilizing Bar codes to ID railroad vehicles. In 1969 Computer Identics Corporation introduces the principal genuine Bar code frameworks at General Trading Company and General Motors offices. In 1970 NAFC (National Association of Food Chains) builds up the Ad-Hoc Committee for U.S. General stores on a Uniform Grocery-Product Code to set scanner tag advancement rules. In 1972 RCA starts an 18-month trial of a bull's-eye standardized tag framework in a store in Cincinnati. In 1973 UPC was introduced, stage from which Bar codes took off. In 1974 pack of Wrigley's biting gum was the main retail item sold utilizing a Bar code scanner at a Marsh store in Troy, Ohio. The abroad research on 2D Bar code innovation started in the late 1980s and they have built up an assortment of code frameworks. The home examination started in 1993. Based on processing some outside pertinent materials, two 2D Bar code

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identification national norms, FPD417(GB/T 17172-1997) and Quick Response Code (GB/T 18284-2000). In 1984, Bar code scanner were present in 33% of grocery stores. In 1994 Toyota subsidiary, Denso Wave, created QR codes to assist in more swift vehicles and part tracking's. According to a report around 2004 80% to 90% of the top 500 companies in the United States were using Bar codes. Quick Response Code (QR Code) discharged by Japanese Denso Company, became ISO all-inclusive standard in 2000. Not withstanding the highlights, for example, enormous data limit, high dependability, the capacity of communicating characters and picture data and solid security favorable circumstances, it likewise has the accompanying fundamental highlights, fast perusing, mistake revision ability [12]-[14].

Fig. 2. Example of visual cue to aid QR code detection (reproduced from [9] with permission)

Detecting the presence of a code, but also in determining the size and position of a QR code symbol in an image, important for correctly framing them. In addition, detection should be fast to allow real-time applications.

A promising approach to address this problem is the rapid object detection framework, proposed by Viola and Jones, and originally applied for face detection [10]. In their framework, detection is based on a cascade of weak classifiers with simple features inspired by Haar wavelets. They achieve an impressive speed in multi-scale face detection, combining simplicity in feature computation with an effective way of focusing processing only in promising regions of the image.

Specifically, in this work we investigate the use of Viola-Jones framework for the detection of finder patterns (FIPs), a fixed pattern located in three corners of any QR code. Since the training framework has many parameters that can be tuned to meet the needs of a particular application, we investigate parameter variation effects in several experimental scenarios. Results are evaluated in terms of hits (true positives) and false alarms (false positives) and they show that a relatively small number of FIP samples in the training set is sufficient to achieve very good detection rates. Furthermore, since the detection step typically presents false alarms, a geometrical constraint based post-processing step is proposed in order to decide if the detected FIPs are or not corners of a QR code symbol.

The rest of this paper is organized as follows. In Section II, the general structure of a QR code is described and Viola-Jones rapid object detection framework is reviewed. In Section III, the proposed method for QR code detection is described. We first justify the decision on detecting FIPs rather than the whole QR code area, then we describe the training and classifier evaluation procedure, which is followed by the description and discussion of an approach for choosing parameter values. In Section IV we describe and discuss the main experimental results with respect to parameter choice. We also show examples of QR code symbol detection in real images. Finally, in Section V, we present a summary of the main results and some steps for future work.

2. Background

A. QR Code Structure

QR codes, short for Quick Response codes, are two-dimensional barcodes that store information in a pattern of black squares arranged on a white background. These codes are capable of encoding various types of data, including alphanumeric characters, binary data, and even kanji characters. QR codes consist of several structural elements, each serving a specific purpose in encoding and decoding information. The structure of a typical QR code includes the following components as in figure 3.

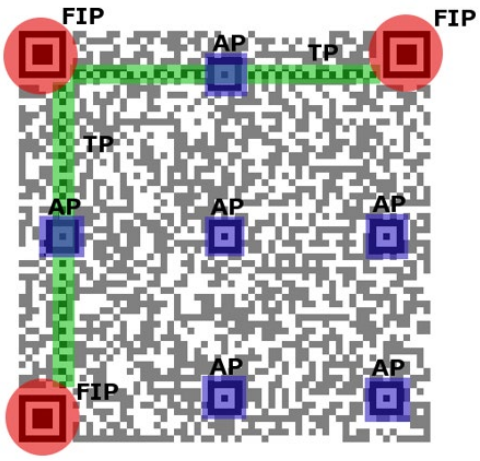


Fig. 3. QR code structure

3. Literature Survey

A literature survey on QR codes and barcodes reveals a plethora of research spanning various fields such as technology, marketing, logistics, and security. Both QR codes and barcodes are widely used for data encoding and retrieval, yet they differ significantly in their structure, functionality, and applications.

Barcodes, initially developed in the 1970s, consist of a series of parallel lines of varying widths representing data. They are commonly found in retail settings for inventory management, product identification, and point-of-sale transactions. Research on barcodes has focused on optimizing their design, decoding algorithms, and application in diverse industries.

On the other hand, QR (Quick Response) codes, invented by Denso Wave in 1994, are two-dimensional matrix barcodes capable of storing significantly more data than traditional linear barcodes. QR codes can encode various data types, including

text, URLs, contact information, and even multimedia content. Their widespread adoption is due to their ability to be scanned quickly by smartphones and other devices equipped with cameras. Literature on QR codes encompasses studies on their applications in marketing, advertising, ticketing, authentication, and supply chain management.

Barcodes, originating in the 1970s, have primarily served retail and inventory management sectors with their linear data encoding. Conversely, QR codes, introduced in 1994, offer a more versatile, two-dimensional format capable of storing various data types. Research encompasses a wide array of fields, from optimizing decoding algorithms for accurate data retrieval to exploring innovative applications such as marketing, healthcare, and education. Security remains a paramount concern, driving efforts to prevent counterfeiting and unauthorized access to encoded information. Furthermore, the usability and accessibility of both barcode and QR code technology have been subjects of investigation, aiming to enhance user experience across different contexts. In marketing, QR codes have emerged as powerful tools for interactive consumer engagement, while in healthcare, their integration streamlines processes like patient identification and medication management. Educational research explores the integration of QR codes into learning materials to facilitate interactive content delivery and assessment methods. Overall, literature on QR codes and barcodes reflects their pervasive influence across various domains and ongoing efforts to innovate and secure their applications.

The usability and accessibility of barcode and QR code technology have been focal points of inquiry, with studies aiming to enhance user experience through intuitive design and universal accessibility features. In marketing, QR codes have emerged as potent tools for interactive consumer engagement, enabling seamless integration of offline and online promotional campaigns. Similarly, healthcare applications leverage QR codes for streamlined processes such as patient identification and medication management, improving efficiency and reducing errors. Educational research explores innovative ways to integrate QR codes into learning materials, enhancing student engagement through interactive content delivery and personalized learning experiences. Overall, the literature on QR codes and barcodes underscores their significant impact across various sectors and ongoing efforts to innovate and secure their applications for the future.

A. Database

The experiments are performed on the images taken from the camera. The images are captured from the different items available including books etc. A database of the different bar code and QR code images is created. The corresponding information of the products are stored in CSV (Comma Separated Values) file type, which allows to add barcodes and QR code in quick manner. The column headers are used to separate the information to create a CSV file. These files are ordered in one format. In the first column, a value is assigned to each of the QR code/Bar code for validation. The second column represents the simple text, structured text, HTML or web content that will be displayed or highlighted after the

Fig. 4. Diagram of database memory

4. Proposed Methodology

The proposing a method for generating both QR codes and barcodes involves a systematic approach encompassing several key steps. Initially, it's imperative to gather requirements, delineating the type of information intended for encoding and the preferred format for the codes, whether it be QR codes, 1D barcodes, or 2D barcodes. Following this, selecting a suitable programming language alongside requisite libraries, such as Python with 'QRcode' and 'barcode', facilitates implementation.

Once the necessary libraries are installed, the generation process begins. For QR codes, employing appropriate library functions enables encoding the desired information, with parameters like size, error correction level, and encoding mode duly specified. Similarly, for barcodes, the chosen barcode type, such as Code 39 or Code 128, dictates the encoding process, integrated with the barcode library functions.

The integration of QR code and barcode generation processes into a cohesive script streamlines output generation. This could entail saving the generated images to files or directly displaying them. Subsequently, rigorous testing ensues to ensure the generated QR codes and barcodes are scannable and accurately capture the encoded information. Any discrepancies warrant rectification, and optimization of the code for efficiency, particularly in scenarios necessitating the generation of large batches of code.

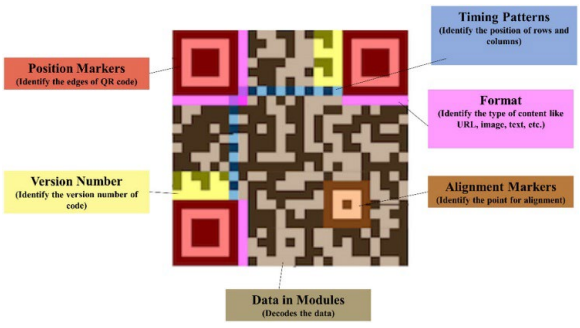
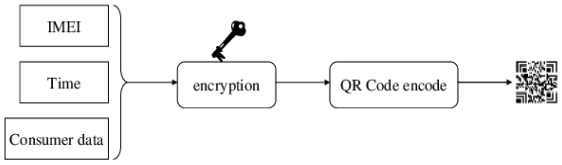
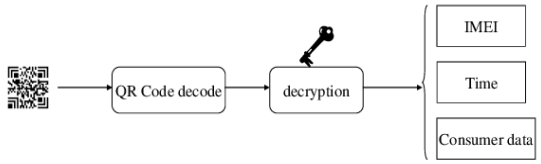


Fig. 5. Data in modules

Detection: We modify the YOLO architecture to specialize in detecting QR codes and barcodes. This involves training the network on a large dataset of annotated images containing diverse examples of QR codes and barcodes. The network learns to recognize the distinctive features of these codes, enabling accurate detection even under challenging conditions such as low lighting and occlusion.



(A) QR Code encoder



(B) QR Code decoder

Fig. 6. Barcode detected from a book by our program

Detecting a barcode from a book can be a useful feature for various applications such as inventory management, library systems, or retail operations. If your program successfully detected a barcode, it opens up possibilities for extracting information encoded in the barcode, such as ISBN numbers for books or product codes for retail items. How can I assist you further with this information

Decoding Once the codes are detected, we employ a combination of traditional decoding algorithms and neural network-based approaches to extract the encoded information. This hybrid approach enhances the robustness of the decoding process, ensuring accurate extraction of information even from damaged or partially occluded codes.

5. System Architecture

The system architecture for both QR codes and barcodes comprises several interconnected components that work together seamlessly to capture, decode, and process the information contained within these codes.

For barcodes, the process typically begins with a barcode scanner or reader, which captures the barcode image using optical sensors. Once captured, specialized decoding software processes the digital signal, interpreting the pattern of bars and spaces according to the specific barcode symbology. This software extracts the encoded data from the barcode, which is then processed by the system based on its application requirements. This might involve updating inventory records, generating sales reports, or identifying products in a retail environment. The decoded data may also be integrated with other systems, such as inventory management or supply chain software.

On the other hand, the system architecture for QR codes follows a similar pattern. A QR code generator creates the QR code based on the provided data, converting it into a matrix of black and white squares according to the QR code standard. A QR code scanner captures the QR code image, which is then decoded by specialized software. This software extracts the encoded data from the QR code, which can include URLs, text, contact information, or Wi-Fi credentials. Like barcodes, the decoded data from QR codes is processed by the system based on its application, and it may also be integrated with other systems for further processing or action.

In both cases, common components include user interfaces for interaction, data storage for storing scanned data, error handling and validation mechanisms, and security measures to protect sensitive information. Overall, the system architecture for both QR codes and barcodes is designed to efficiently capture, decode, and utilize the encoded information for various applications

QR Code System Architecture:

QR Code Generator: This component generates the QR code based on the data provided. It converts the data into a matrix of black and white squares according to the QR code standard.

QR Code Scanner/Reader: Similar to barcode scanners, QR code scanners capture the QR code image using optical sensors. They convert the image into a digital signal for processing.

QR Code Decoding Software: Once the QR code is captured, decoding software processes the digital signal to extract the encoded data. QR codes can contain various

Data Processing: The decoded data is then processed by the system based on its application. For example, if the QR code contains a URL, the system may open a web browser to the specified URL. If it contains contact information, it may add the contact to an address book.

Integration: Similar to barcodes, QR code data may need to be integrated with other systems for further processing or action.

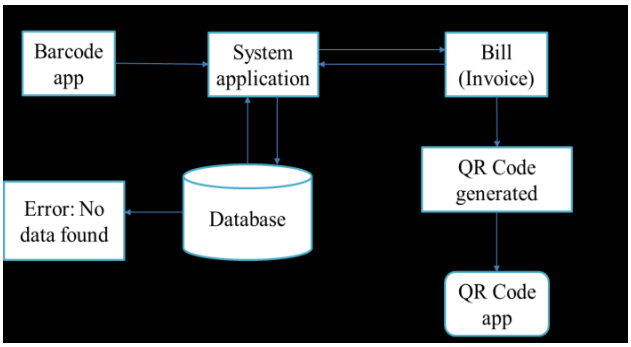


Fig. 7. System architecture of QR code

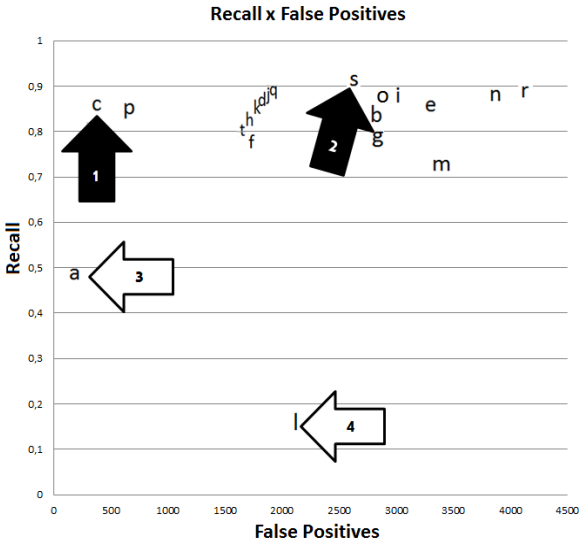
6. Experimental Results

Results and discussions regarding QR codes and barcodes encompass a broad spectrum of applications and considerations. QR codes, characterized by their two-

dimensional matrix structure, demonstrate superior data capacity compared to traditional barcodes. Studies have emphasized QR codes' versatility in encoding complex data types, including URLs, contact information, and multimedia content, making them indispensable in various industries. On the other hand, barcodes are noted for their simplicity and efficiency in encoding and decoding data, particularly in high-speed scanning applications like retail checkout processes. Security remains a significant focus, with research exploring methods such as encryption and digital signatures to protect against counterfeiting and unauthorized access. Additionally, discussions often center on the balance between security measures and usability, ensuring efficient authentication processes without sacrificing user experience. In supply chain and logistics, both QR codes and barcodes play vital roles in inventory tracking, product authentication, and logistics optimization, driving discussions on interoperability standards and data exchange protocols.

Real image processing:

FIP detection rate superior to 90% on test images are achieved with some classifiers. Squares in the images correspond to FIP candidates detected in the first step while line segments indicate pairwise relations taken into consideration to decide if the corresponding FIPs are or not corners of QR codes. An arrow point.



#	MODE	MTS	SYM	NS	FA	ST	SAMPLES	SIZE
a	ALL	0	N	2	0.5	15	4000	20
b	BASIC	0	N	2	0.5	15	4000	20
c	BASIC	0	Y	1	0.4	13	4000	20
d	BASIC	0	Y	1	0.5	15	1000	20
e	BASIC	0	Y	1	0.5	15	2000	20
f	BASIC	0	Y	1	0.5	15	4000	10
g	BASIC	0	Y	1	0.5	15	4000	12
h	BASIC	0	Y	1	0.5	15	4000	14
i	BASIC	0	Y	1	0.5	15	4000	16
j	BASIC	0	Y	1	0.5	15	4000	18

#	MODE	MTS	SYM	NS	FA	ST	SAMPLES	SIZE
k	BASIC	0	Y	1	0.5	15	4000	20
l	BASIC	0	Y	1	0.5	15	4000	6
m	BASIC	0	Y	1	0.5	15	4000	8
n	BASIC	0	Y	1	0.5	15	6000	20
o	BASIC	0	Y	1	0.5	15	8000	20
p	BASIC	0	Y	1	0.6	23	4000	20
q	BASIC	0	Y	2	0.5	15	4000	20
r	BASIC	0	Y	3	0.5	15	4000	20
s	BASIC	0	Y	8	0.5	15	4000	20
t	BASIC	10	Y	2	0.5	15	4000	20

Fig. 8. Recall × FP for classifiers obtained with different training parameters

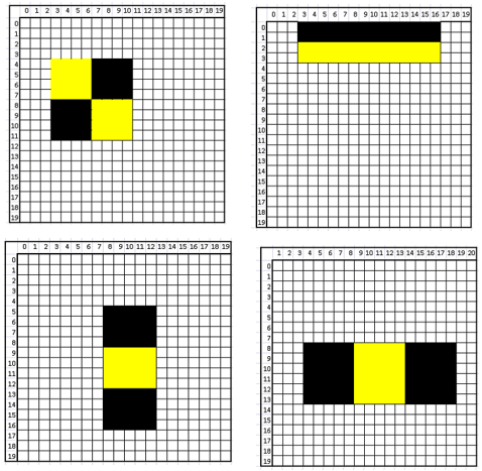


Fig. 9. The two main features when sample symmetry is (top row) and is not (bottom row) supposed

These results were obtained with a classifier trained with the same parameters of classifier i, except the number of stages (ST) that was set to 17. The choice of this classifier was based on the fact that its performance in recall was very close to the best one observed (classifier s) and its simplicity (number of splits equal to 1 against the 8 splits of classifier s). Furthermore, classifier i considers a smaller window size (16 × 16), and hence it should be able to recognize smaller.

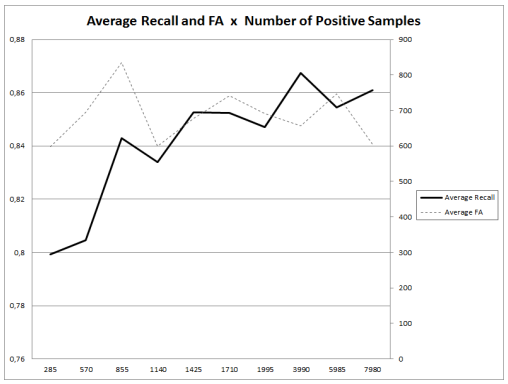


Fig. 10. Effect of augmenting the number of positive samples. average of five training runs

FIPs. These images as well as additional resulting images can be found from URL http://www.vision.ime.usp.br/demos.

Fig. 11. FP=5 and QR code correctly detected

Fig. 12. FP=0 and QR code correctly detected

7. Conclusion and Future Work

In conclusion, the literature survey on QR codes and barcodes illuminates their pervasive influence across numerous domains, from retail and logistics to healthcare and education. Barcodes, with their linear data encoding, have long been integral to inventory management and retail operations, while QR codes, offering a versatile two-dimensional matrix format, have unlocked new possibilities in data storage and retrieval. Research in this field has addressed critical issues such as decoding accuracy, security, usability, and application innovation. Moving forward, the future scope of QR codes and barcodes appears promising, with opportunities for further advancements in decoding algorithms, enhanced security measures to combat counterfeiting and data breaches, and the exploration of novel applications in emerging sectors like augmented reality and Internet of Things (IoT). Additionally, as technology continues to evolve, the integration of QR codes and barcodes with other technologies such as blockchain and machine learning holds immense potential for revolutionizing various industries. Moreover, addressing challenges related to standardization, interoperability, and sustainability will be essential for maximizing the utility and longevity of QR codes and barcodes in the digital age. Overall, the ongoing research and innovation in this field underscore the enduring relevance and potential of QR codes and barcodes as indispensable tools for data encoding, communication, and interaction in the years to come.

Future work will focus on further improving the efficiency and robustness of our approach, exploring techniques such as data augmentation, domain adaptation, and transfer learning to enhance performance across different domains and environments. Additionally, we plan to extend our approach to handle the decoding of QR codes and barcodes, enabling end-to-end automation of barcode scanning systems.

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