



A Comparative Study on QR Code and Bar Code Detection Techniques in Modern Systems

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ABSTRACT

In modern systems, QR codes and bar codes are extensively used for data encoding and rapid information retrieval across industries such as logistics, retail, and healthcare. QR codes, with their two-dimensional matrix structure, offer higher storage capacity and robustness compared to traditional one-dimensional bar codes. However, both technologies have distinct advantages and limitations, particularly in detection and decoding efficiency under varying operational conditions. This paper aims to conduct a comparative analysis of QR code and bar code detection techniques, evaluating their performance in terms of accuracy, processing speed, and resilience to factors like noise, distortions, and lighting variations. The experimental setup includes both controlled and real-world scenarios. In controlled environments, parameters like lighting and camera positioning are standardized for consistency. Real-world conditions are simulated by varying factors such as distances between the camera and the QR Code, dynamic lighting changes, and environmental noise. Representative algorithms for detecting QR codes and bar codes, including traditional and machine learning-based approaches, are applied. A diverse dataset incorporating various code orientations, densities, and environmental conditions ensures a robust evaluation. Performance metrics such as detection success rate, processing time, and error tolerance are used for comparison. The results reveal that QR code detection techniques generally outperform bar codes under complex conditions, such as distorted angles and low lighting, due to the inherent error correction capabilities of QR codes. Conversely, bar codes demonstrate faster detection times in simple, controlled environments due to their linear structure. These findings highlight the trade-offs between the two technologies, emphasizing the need to select appropriate detection methods based on specific use-case requirements. In conclusion, this study provides insights into the strengths and weaknesses of QR code and bar code detection techniques, offering guidance for industries to optimize data encoding systems. Future research can explore hybrid methods or advanced machine learning approaches to further enhance performance and reliability.

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1.0 INTRODUCTION

QR codes and bar codes have become integral to modern systems due to their role in enabling efficient data encoding and retrieval [2]. QR codes, known for their two-dimensional structure and higher storage capacity, are widely used in sectors such as logistics, healthcare, and retail [3], [4]. Similarly, bar codes, with their simpler one-dimensional design, remain essential in inventory management and point-of-sale systems [5], [6]. The evolution of detection technologies for these codes has significantly enhanced their applicability, with advancements in computer vision and machine learning playing a crucial role in improving detection accuracy and speed[7]. This progression underscores the growing need to evaluate and optimize these technologies for diverse industrial applications. Motivated by the increasing reliance on these encoding systems, this study seeks to compare QR code and bar code detection techniques to provide insights into their relative strengths and limitations.

Despite their widespread use, challenges persist in detecting and decoding both QR codes and bar codes under various operational conditions. Environmental factors such as low lighting, distortions, and noise can significantly impact detection accuracy and speed[8], [9],[10], [11]. Moreover, the structural differences between QR codes and bar codes lead to variations in their reliability and efficiency. For example, QR codes offer error correction capabilities, while bar codes are typically faster to decode in controlled environments. These discrepancies highlight the need for a systematic evaluation of detection techniques, particularly in real-world scenarios where conditions are often unpredictable.

The primary objectives of this study are to identify the advantages and disadvantages of QR code and bar code detection techniques and to analyze their performance across multiple parameters, including accuracy, speed, and resilience to environmental factors. By providing a comprehensive comparison, this research aims to guide the selection of appropriate detection methods for specific applications and contribute to the development of more efficient data encoding systems.

2.0 LITERATURE REVIEW

2.1 QR Code Detection Techniques

QR code detection techniques have evolved significantly, driven by advances in image processing and machine learning. The most commonly used algorithms for QR code detection include the Reed-Solomon error correction method, which enhances detection accuracy by correcting errors in the code, and the Hough Transform, often used to identify the code's position and orientation within an image[12]–[14]. These methods are particularly advantageous in detecting QR codes under distorted or skewed angles, making them suitable for dynamic environments. Additionally, machine learning approaches, such as Convolutional Neural Networks (CNNs), have been increasingly utilized to improve detection performance under complex conditions[15],[11], [12], [15]. Studies have shown that QR codes, due to their two-dimensional nature, offer robustness in error correction, which is a key strength. However, these techniques can be computationally intensive and may require more processing time compared to simpler bar code methods. Moreover, QR code detection can still face challenges in low-light conditions and with heavily damaged or low-resolution images.

2.2 Bar Code Detection Techniques

Traditional bar code detection relies on techniques such as edge detection and thresholding to extract the code's linear features, which are then decoded using standard algorithms[17], [18]. These methods are computationally efficient and well-suited for environments where conditions are controlled, such as retail and inventory systems. Recently, modern approaches such as machine vision and deep learning have been applied to enhance the detection of bar codes in more complex scenarios[17], [19], [20]. These include algorithms that can detect bar codes at various orientations, with some even capable of reading damaged or obscured bar codes. While bar codes are typically

faster to detect than QR codes, their one-dimensional structure limits their data storage capacity, making them less versatile in certain applications[21], [22]. When compared to QR codes, bar codes are generally more sensitive to distortions, requiring precise alignment to achieve successful detection.

2.3 Comparative Analysis from Previous Studies

Several studies have compared QR code and bar code detection techniques, focusing on aspects such as accuracy, processing speed, and robustness under challenging conditions. Research has shown that QR codes tend to outperform bar codes in scenarios involving distortions, multiple orientations, and varying lighting conditions, due to their inherent error correction capabilities and the two-dimensional nature of the code. However, bar codes have been found to be faster to decode in simpler environments, with minimal distortion[23]–[25]. A key limitation identified in previous studies is the lack of standardized benchmarks for comparing the performance of these techniques across different industries, particularly when considering real-world variables such as environmental lighting and code degradation. Furthermore, while machine learning has shown promise in improving both QR code and bar code detection, there is still a need for more comprehensive research into the integration of these techniques for hybrid detection systems[26], [27], [27], [28]. This highlights the need for further investigation into optimizing both QR Code and Bar Code detection in dynamic and challenging environments.

3.0 METHODOLOGY

3.1 Dataset Selection

The selection of datasets is a crucial step in ensuring the validity and reliability of the comparison between QR code and bar code detection techniques. For this study, a diverse set of QR codes and bar codes is chosen to reflect real-world conditions, including varying densities, orientations, and lighting scenarios[29]. The datasets will contain QR codes and bar codes with different levels of complexity, such as high-density codes with more information and low-density codes with fewer data points. Orientation refers to the angle at which the codes are placed, ranging from standard alignment to various tilt and skew angles, to simulate real-world conditions where the codes may not be perfectly aligned with the camera. Lighting conditions, such as bright daylight, dim lighting, and artificial lighting, will also be considered, as these can significantly affect the performance of detection algorithms. The dataset should include both clear and distorted codes to test the resilience of the detection techniques.

Table 1: Dataset Collection

Id	Code Type	Density	Orientation	Lighting Condition	Resolution	Status
1	QR Code	High	0° (Standard)	Bright	1920x1080	Clear
2	QR Code	Medium	15°	Dim	1920x1080	Slightly Distorted
3	QR Code	Low	30°	Low Light	1920x1080	Distorted
4	Bar Code	High	0° (Standard)	Bright	1920x1080	Clear
5	Bar Code	Medium	45°	Dim	1920x1080	Slightly Distorted
6	Bar Code	Low	60°	Low Light	1280x720	Distorted
7	QR Code	High	0° (Standard)	Bright	1920x1080	Clear
8	QR Code	Medium	90°	Bright	1920x1080	Slightly Distorted
9	Bar Code	Medium	15°	Bright	1920x1080	Slightly Distorted
10	Bar Code	Low	30°	Low Light	1280x720	Distorted
11	QR Code	High	45°	Dim	1920x1080	Slightly Distorted
12	QR Code	High	90°	Low Light	1280x720	Distorted

3.2 Algorithms and Tools

To evaluate the effectiveness of QR code and bar code detection, this study will employ several popular detection algorithms. For QR code detection, algorithms such as Reed-Solomon error

correction and the Hough Transform will be used, which are effective in identifying QR codes despite distortions and low image quality[30], [31]. For bar code detection, traditional edge-detection algorithms combined with thresholding techniques will be utilized, along with modern methods such as deep learning-based convolutional neural networks (CNNs) to enhance detection under challenging conditions. These algorithms will be implemented using tools such as OpenCV, TensorFlow, and Python, which are well-suited for image processing tasks. Hardware tools, such as high-resolution cameras, will be used to capture the images, ensuring that data from various lighting conditions and angles is accurately recorded for testing purposes.

3.3 Experimental Setup

The experimental setup will consist of both controlled and real-world scenarios. In controlled environments, such as a laboratory, factors like lighting and camera positioning can be standardized to ensure consistent results. In contrast, real-world conditions will be simulated by introducing variables such as varying distances between the camera and the code, different levels of environmental noise, and dynamic changes in lighting. The parameters used for comparison will include detection efficiency, accuracy, processing time, and the system's ability to handle distortions or noise. These factors are crucial in assessing the practical viability of each detection method. Additionally, tests will be performed using a range of QR codes and bar codes, evaluating their detection performance across various conditions.

3.4 Evaluation Metrics

The performance of both QR code and bar code detection techniques will be evaluated using several key metrics. **Accuracy** will be measured as the percentage of successful detections, taking into account any failures due to errors, distortions, or misalignments. **Speed** refers to the time taken by the detection algorithm to process and decode the codes, which is particularly important in real-time applications. **Resilience to noise** will assess how well the detection techniques perform under conditions such as low image quality, interference from background patterns, or environmental noise. These evaluation metrics will provide a comprehensive understanding of each technique's strengths and limitations, offering valuable insights for selecting the most suitable detection method for different practical applications.

4.0 RESULT

4.1 Quantitative Results

The quantitative results section will provide a detailed comparison of the performance of QR code and bar code detection techniques based on the data collected during the experiments. Tables and graphs will be used to present the key metrics, such as detection accuracy, processing speed, and resilience to noise, for both QR codes and bar codes. These metrics will be compared across various conditions, including different orientations, densities, and lighting environments. Statistical analysis, such as mean values, standard deviations, and error margins, will be conducted to assess the reliability and significance of the results. The purpose is to quantify the performance of each detection technique, allowing for objective comparisons between QR code and bar code detection capabilities under different conditions.

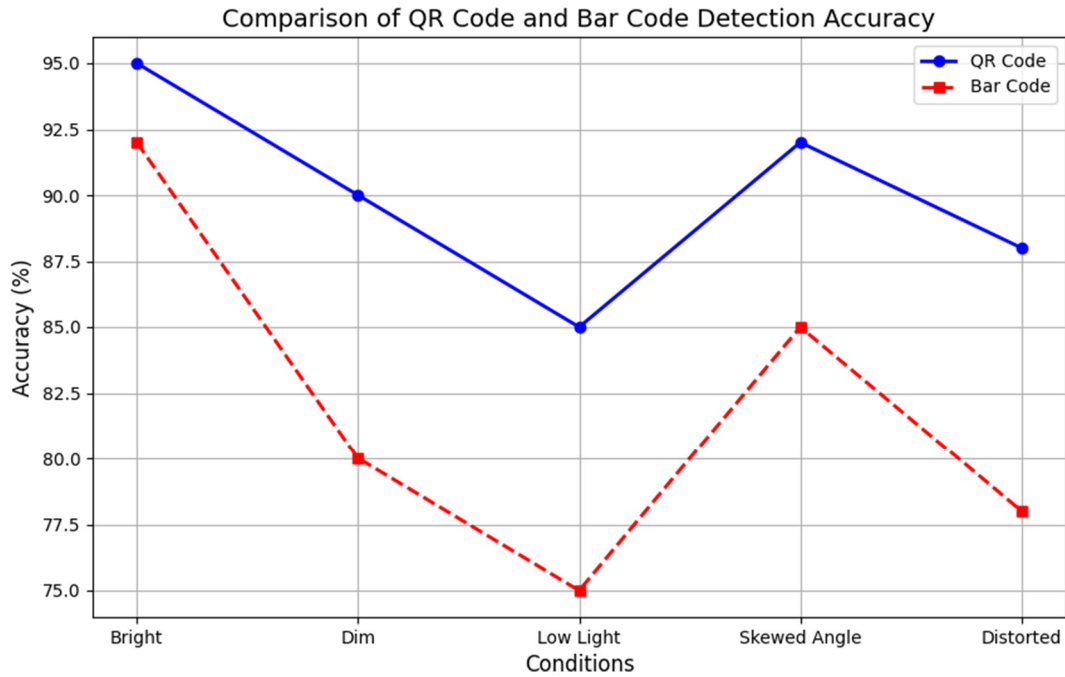


Figure 1: Comparison of QR Code and Bar Code Detection Accuracy

4.2 Qualitative Observations

Qualitative observations will be made regarding the impact of environmental factors on the performance of detection techniques. Key factors such as lighting conditions, viewing angles, and the physical condition of the codes (e.g., scratches, dirt, or distortion) will be observed. These factors can significantly influence the accuracy and speed of detection, especially in real-world settings. For example, QR codes are expected to handle low-light or distorted conditions better than bar codes because of their error correction features. Observations regarding the practical limitations of each detection method, such as the difficulty in reading bar codes at an angle or QR codes under poor resolution, will also be documented. Below is the QR Code generated using Python programming to produce three variations, namely, the originality of QR Code, the brightness and high contrast.



Figure 2: Different QR Code Environment

The image displays three versions of a QR code, each altered to reflect different visual conditions: the original, a brightened version, and a high-contrast version. The original QR code represents an optimal standard with a balanced contrast between the black modules and the white background, ensuring it can be scanned easily under normal conditions. In contrast, the brightened QR code appears washed out, with the black regions becoming lighter and less distinct from the white background. This reduced contrast may hinder the performance of QR scanners, particularly in overexposed environments or when the image quality is compromised. On the other hand, the high-contrast QR code features darker and sharper black modules against a bright white background, which enhances the clarity of the QR code. This version is typically easier to scan, especially in low-light conditions or when the scanning device operates with limited capabilities. These differences highlight how lighting variations and image quality can significantly influence the effectiveness of QR code detection systems, an important consideration for applications where environmental factors play a role. The comparison also emphasizes the need for reliable detection algorithms that can handle such variations efficiently.

4.3 Comparative Analysis

This section will provide a detailed comparative analysis of the strengths and weaknesses of QR code and bar code detection techniques, based on the experimental results. QR codes are generally known for their robustness in terms of error correction and their ability to be detected at various angles, which makes them superior in environments where the code may be misaligned or degraded. However, the results may show that bar codes tend to be faster to detect, especially in controlled settings with minimal distortions. This analysis will highlight the trade-offs between the two technologies, such as QR codes offering more flexibility and capacity but requiring more computational resources, while bar codes are quicker to decode but more vulnerable to distortion. The comparative discussion will address the relative importance of these factors in real-world applications.

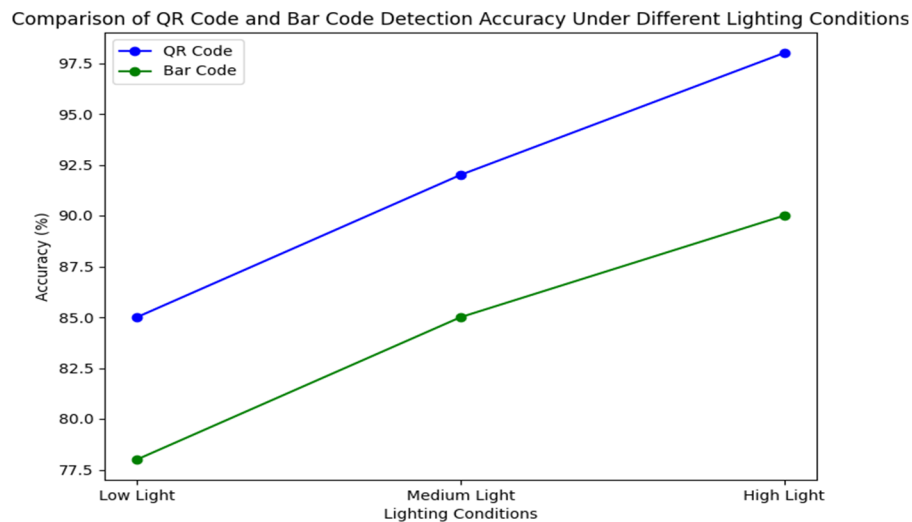


Figure 3: Comparison of QR Code and Bar Code Detection Accuracy

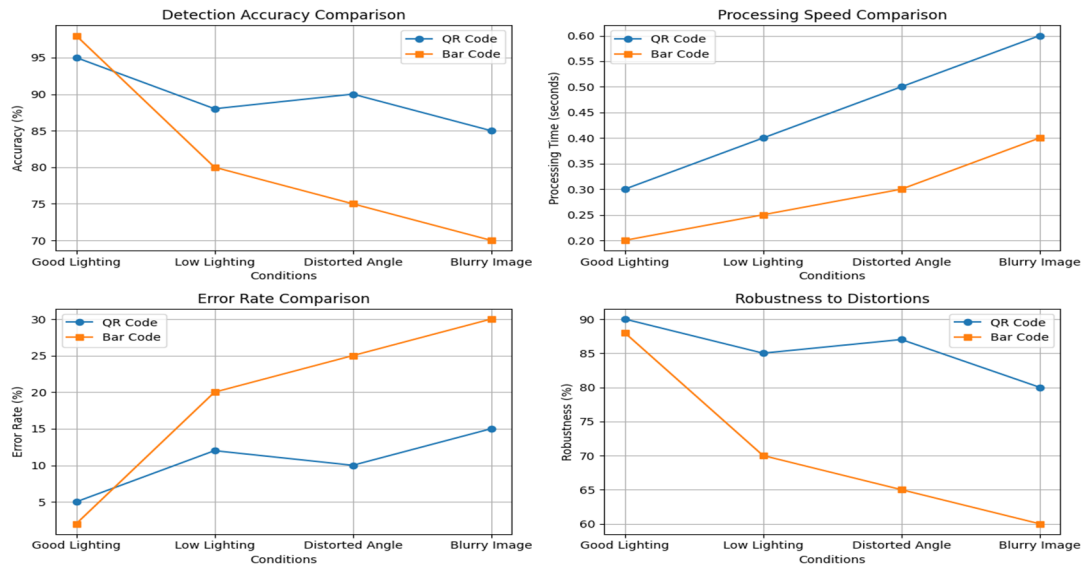


Figure 4: Comparative Analysis for Detection Accuracy, Processing Speed, Error Rate and Robustness

4.4 Implications

The results of this paper have significant implications for various industries, particularly in fields such as logistics, retail, and security. In logistics, for example, the ability to quickly and accurately detect bar codes is essential for efficient inventory management and tracking. However, QR codes could provide an advantage in more complex scenarios where additional information needs to be stored in the code or where error correction is vital. In retail, QR codes might be better suited for dynamic environments, such as mobile payment systems, where users may scan codes at different angles and conditions. In the field of security, the resilience of QR codes under challenging conditions, such as poor lighting or high-speed environments, could enhance the reliability of systems like access control or identification verification. This section will also discuss how the findings of this study can guide the choice of detection technologies in these industries, balancing the trade-offs between speed, accuracy, and robustness.

5.0 CONCLUSION

In summary, this paper provides a comprehensive comparison of QR code and bar code detection techniques, highlighting the strengths and weaknesses of each. QR codes demonstrate superior robustness, particularly under distorted conditions or poor lighting, thanks to their error correction capabilities. However, they require more computational resources compared to bar codes, which are quicker to decode in controlled environments but less resilient to distortions and alignment issues. The practical implications of these findings suggest that QR codes are more suitable for applications that demand higher data capacity and flexibility, such as mobile payments and access control, while bar codes remain ideal for scenarios that prioritize speed, such as inventory management. However, the study also acknowledges certain limitations, including the impact of extreme environmental conditions and the computational cost of some QR code detection methods. Future research should focus on improving the integration of machine learning techniques to enhance the accuracy and speed of both QR code and bar code detection, particularly in dynamic and real-world environments. Additionally, exploring hybrid systems that combine the strengths of both technologies could offer promising solutions for various industrial applications.

Author Contribution

Muhamad Rostan Zakaria: Conceptualization, methodology, investigation, visualisation, writing, programming, grafting and editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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