*Journal of Computers and Applied Science Education*

©2026 ISSN 2409-7284 (online)
Volume **6**, Number **1**, March **2026**

# Applications of the QR code: A review

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Received January 15, 2026, revised February 3, 2026, accepted February 8, 2026.

Abstract. *This paper offers a comprehensive overview of the widespread application and transformative potential of quick response (QR) code technology across diverse domains. Initially designed in the automotive industry to track parts efficiently, the QR code has evolved into a ubiquitous tool for instant information access and seamless user interaction through reliable smartphone scanning. The paper delves into four key areas: In education, QR codes enhance learning experiences by linking physical materials to digital resources, streamlining instruction, and promoting interactive study. In commerce, they expedite transactions via contactless payments and significantly boost customer engagement through promotional content. In information security, advanced encryption techniques enable secure sharing of confidential data via the QR code. Furthermore, for general information access, they bridge physical and digital worlds, aiding both users and automated systems. Real-world examples illustrate their integral role in daily operations and inclusive, accessible solutions. Future trends indicate expanding adoption into new sectors, paving the way for more connected, efficient, and intelligent services globally.*
**Keywords:** QR code, Education, Information security, Commercial activities, Accessing and obtaining information.

1. **Introduction.** Quick response (QR) codes, invented by Denso Wave [1], are two-dimensional barcodes that encode information as binary images of black and white modules. Information is encoded in the arrangement of black modules, which can be decoded by scanning devices. In everyday life, people can quickly decode QR codes using smartphones or dedicated scanners. Due to their fast decoding speed and convenience, the QR code has been widely adopted across various industries [2, 3], including education, commerce, information security, and for accessing and retrieving information, as illustrated in Figure 1.

QR codes have been increasingly utilized in education [4]. Jeon et al. propose integrating the QR code into English language classes [5], aiming to develop a "Smart English teaching model using QR codes" that leverages modern technology to enhance student engagement and enjoyment in learning English. Similarly, the QR code has been applied in physics instruction, where it helps streamline teaching processes and enriches the learning experience [6]. Their use in physics lessons not only supports the

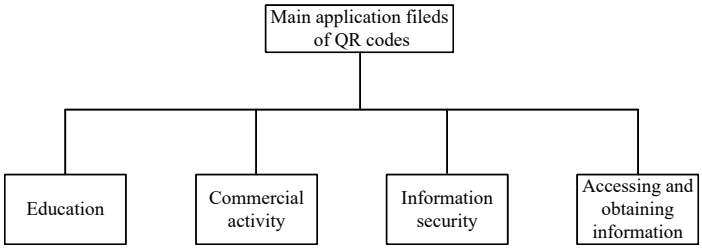


FIGURE 1. Main application fields of QR codes.

achievement of educational objectives but also increases student interest and fosters skill development. In addition, QR codes have also promoted the development of mobile learning, enabling students to access educational content anytime and anywhere [7]. They have been employed to improve pronunciation and expand vocabulary in language learning [8], and have proven effective in enhancing overall student learning outcomes [9]. In library services, the QR code has played a significant role in promoting accessibility and efficiency [10]. Researchers have developed digital and smart library systems based on QR code technology [11], making library resources easier to access and use [12]. Overall, QR codes have demonstrated significant potential and utility in educational contexts.

Commercial activities also widely utilize the QR code [13]. Pandit et al. employ QR codes to facilitate commercial operations [14]. The QR code can enhance the consumer's shopping experience [15]. QR code menus are used to reduce service time and improve customer experience [16]. The use of QR codes enhances the consumer experience, thereby increasing commercial activity and contributing to social prosperity. Jagodic et al. utilize the QR code to generate and deliver information [17]. QR codes have been applied to digitize and track product information, ensuring food safety [18]. Distinguishing product details and tracking production information through the QR code not only assists producers in product management but also protects consumers' rights and interests, benefiting the business. Encrypted QR codes have been used to enable e-payment transactions [19]. The QR code makes transactions more convenient for both sellers and consumers. Vending machines complete transactions using QR codes [20], making the transaction process more efficient. This convenience fosters the prosperity of commerce. The QR code has been applied in the tourism industry [21]. Tourists obtain information about scenic spots by scanning QR codes [22]. The QR code can promote the development of the tourism industry and, consequently, drive business growth. QR codes facilitate economic development by streamlining transactions, enhancing consumer experiences, and enabling efficient information sharing across industries.

A secure QR code is employed to protect information security [23, 24], demonstrating its applicability in this field. An optical encryption method based on QR codes is proposed in [25]. The QR code has also been used to enhance searchable symmetric encryption schemes [26], thereby improving the overall efficiency and functionality of encryption systems. Singhal et al. utilize QR codes in combination with smartphones to achieve degree certificate authentication [27]. Furthermore, integrating the QR code with secret sharing (SS) schemes enables secure online document authentication [28], where the SS scheme encrypts the secret image into shares. Lin proposed a SS scheme using QR codes as shares [29], and Pan et al. developed a color SS scheme using color QR codes as meaningful shares [30]. Meaningful shares reduce suspicion from attackers, thus enhancing the security of the SS system. The QR code has also been applied in electronic access control: Huang et al. present an access control system using QR codes [31], and Bui et al. use the QR code together with a Raspberry Pi processor to secure door locks for classrooms or laboratories [32], showing that QR codes can facilitate secure and efficient electronic access control. Additionally, Bui et al. embed hidden information into the QR code [33], and an algorithm for text hiding using QR codes is proposed in [34], illustrating that information-hiding techniques can be effectively combined with QR codes. Overall, the QR code can be integrated with various cryptographic and security mechanisms to enhance information security in multiple ways.

Accessing information has become increasingly convenient due to the use of QR codes. People can easily retrieve information by scanning the QR code [35]. Jiang et al. design a system that uses QR codes in conjunction with You Only Look Once version 5 (YOLOv5) to perform tasks such as opening different warehouse doors [36], demonstrating how the QR code can facilitate access to information and physical resources. Eken et al. propose a new tracking system that enables users to view the real-time locations of buses using QR codes [37]. Meanwhile, Bach et al. utilize QR codes for robot localization [38],

illustrating that QR codes can be effectively used to access location-based information. In the medical field, Czuszynski et al. employ the QR code to enable interaction with medical data [39], and Lai et al. report that QR codes have assisted medical students in their studies [40], highlighting the applicability of QR codes in healthcare. Prasad et al. develop an information management system based on QR codes [41], and Royani et al. design a mobile application leveraging QR code technology [42]. Utilizing QR codes to access and obtain information offers significant convenience to users across various domains.

This paper provides a comprehensive overview of the applications of QR codes, presenting specific examples in fields such as education, commercial activities, information security, and information access. It describes and analyzes how QR codes are utilized in each domain, aiming to enhance readers' understanding of their functionality and practical value. By detailing both the fundamental characteristics and diverse applications of QR codes, the paper enables readers to gain a thorough understanding of their potential. This knowledge not only supports more effective use of QR codes in everyday life and various industries but also inspires the development of new application areas in the future.

This paper is organized as follows. Section 2 explains QR code concepts and background. Section 3 covers applications in education. Section 4 addresses commercial uses. Section 5 discusses roles in information security. Section 6 describes ways QR codes help access information. Section 7 summarizes the conclusion and looks to the future.

## 2. **Preliminaries.**

This section provides an overview of fundamental knowledge about the QR code. Section 2.1 presents the key characteristics of QR codes, including their structure and functional features. The encoding process of the QR codes is explained in Section 2.2, detailing how data is converted into a two-dimensional barcode format. Section 2.3 describes the decoding process, outlining how scanners and devices interpret the QR code to retrieve the embedded information.

### 2.1. **Characteristics of the QR code.**

QR codes were invented by Denso Wave. They not only possess the advantages of large information capacity and high reliability common to one-dimensional barcodes and other two-dimensional barcodes, but also feature high-speed reading and omnidirectional scanning capability. A QR code consists of black and white square modules arranged in a grid pattern. The size of a QR code is $l \times l$ modules, as illustrated below:

$$l = 17 + 4v, \tag{1}$$

where $v$ is the version. QR codes have 40 versions, ranging from 1 to 40. Every version supports a different data capacity. For each increment in the version number, the length and width of the QR code increase by four modules.

Different arrangements of black and white modules form the function patterns and the encoding region, as illustrated in Figure 2. The function patterns include finder patterns, timing patterns, separators, and alignment patterns, which assist in detecting and properly aligning the QR code during scanning. The encoding region contains format information, version information, data codewords, and the error correction codeword (ECC). Each codeword is composed of eight modules. Together with the quiet zone—the blank margin surrounding the code—the function patterns and the encoding area collectively constitute a complete QR code.

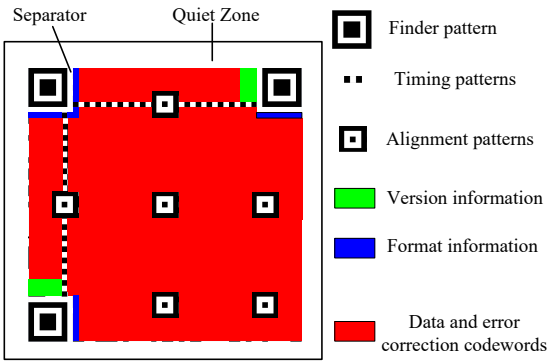


FIGURE 2. The structure of a QR code.

The finder pattern consists of three identical position detection patterns located at the upper left, upper right, and lower left corners of the QR code symbol, as shown in Figure 2. Each finder pattern is

composed of three overlapping concentric squares: a black module center, a surrounding white module layer, and an outer black module layer. This creates a distinctive square-within-square structure. The probability of such a configuration appearing randomly within the symbol is extremely low. This enables reliable and rapid detection of the QR code within the scanner's field of view. By identifying these three finder patterns, the scanning device can determine the position, orientation, and skew of the QR code.

Horizontal and vertical timing patterns are formed by alternating black and white modules. These run between the finder patterns along the x-axis and y-axis. Each alignment pattern resembles a smaller version of the finder pattern, with three overlapping concentric squares. Alignment patterns are used to correct image distortion in larger QR codes. The number and placement of these patterns depend on the QR code version. Alignment patterns appear in all versions from version 2 onwards.

The encoding region contains the data codewords, ECCs, format information, and version information (for versions 7 and above). Format information stores error-corrected data about the error correction level and mask pattern used. This information is necessary for decoding the symbol correctly.

The QR code includes ECCs, enabling it to detect and correct a certain number of errors caused by damage, noise, or poor printing. Its error correction capability is summarized in Table 1. There are four levels in QR codes. Each offers a different degree of resilience. Level L allows correction of approximately 7% of the codewords if corrupted. Level M can correct up to about 15%. Level Q up to 25%, and level H up to approximately 35% of damaged data. These percentages are approximate and represent the maximum proportion of codewords that can be restored. The actual correction capacity varies depending on the QR code's version and the distribution of errors. Higher versions generally contain more ECCs. This built-in redundancy ensures reliable data retrieval even when the code is partially obscured or degraded.

Table 1. The ability of error correction.

| Correction level | Ability (approximate) |
|---|---|
| L | 7% |
| M | 15% |
| Q | 25% |
| H | 35% |

A QR code consists of many codewords, each made up of eight modules. If any module in a codeword is unreadable or damaged, the entire codeword is marked incorrect. The ECC works at the codeword level, letting the QR code recover a set number of corrupted codewords. The exact number depends on the version and error correction level. For example, version 4 at Level L (4-L) allows correction of up to 10 erroneous codewords per data block. If 11 or more codewords in a block are corrupted, error correction fails, and decoding is impossible with a standard decoder.

Table 2. The capacity of the error correction.

| Version | Level | Number of blocks | Correction capacity per block ($c$, $d$, $r$) |
|---|---|---|---|
| 4 | L | 1 | (100, 80, 10) |
| | M | 2 | (50, 32, 9) |
| | Q | 2 | (50, 24, 13) |
| | H | 4 | (25, 9, 8) |

The $c$ is the number of all codewords, $d$ refers to the number of data codewords, and $r$ denotes the number of ECCs.

2.2. **The Encoding of the QR Code.** The encoding process of a QR code is carried out in the following steps:

**Step 1**: **Data Analysis**

Analyze the input data stream to determine the encoding mode. This could be numeric, alphanumeric, byte, or Kanji. QR codes use extended interpretation and encode various character sets efficiently by choosing the right data mode. Select the level L or M or Q or H. If no version is specified, use the smallest QR code version that fits the data.

**Step 2**: **Data Coding**

Convert the input into a bitstream based on the chosen encoding mode. Insert a mode indicator before each segment to specify the current data mode. When modes switch, include the correct mode indicator. Add a terminator if required to mark the end of the sequence. Split the bitstream into 8-bit segments to form codewords. If there are too few codewords, pad with more bits and codewords to fill the data capacity.

**Step 3**: **Error Correction Coding**

Divide the data codewords into blocks based on the version and error correction level. For each block, generate ECCs using Reed-Solomon algorithms. Append these ECCs to their data codeword blocks.

**Step 4**: **Construct Final Message**

Concatenate the data codewords and ECCs from all blocks in the correct order to create the final codeword sequence. Add any remaining bits, if required by format specifications.

**Step 5**: **Arrange Modules in the Matrix**

Place finder patterns, separators, alignment and timing patterns in their fixed spots within the $l \times l$ matrix. Then, systematically add codeword bits to the remaining matrix areas, following a specific path.

**Step 6**: **Add the Mask**

Use the scoring system to evaluate the patterns and select the mask with the highest score. Apply an XOR operation between this mask and the encoded area.

**Step 7**: **Add Format and Version Information**

Add the information on the formatting and version to generate a decodable QR code.

All encoding steps are shown in Figure 3. Steps 1 through 7 include data analysis, data coding, error correction coding, construction of the final message, matrix arrangement, masking, and adding format and version info. Following these, a complete and decodable QR code is generated.

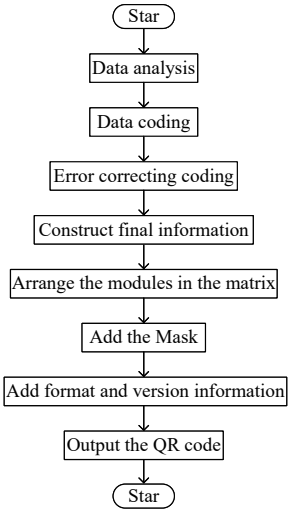


FIGURE 3. The encoding process of the QR code.

2.3. **The Decoding of the QR Code.** The decoding process, from recognizing a QR code to outputting the original information, is the inverse of the encoding procedure, as illustrated in Figure 4. The decoding steps of the QR code are as follows:

Step 1: Start by locating and recognizing the QR code, converting it into a numerical matrix where dark and light modules are identified as 0 and 1.

Step 2: Determine format and the version of the QR code.

Step 3: Use the mask pattern to remove the mask from the encoding region.

Step 5: With the mask removed, apply the module arrangement rules to recover data codewords and ECCs.

Step 6: Correct errors using ECCs.

Step 7: Decode data codewords.

Step 8: Finally, output the final result.

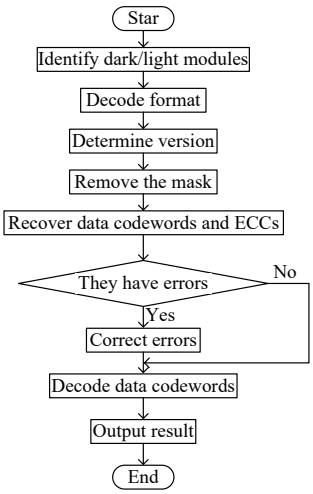


FIGURE 4. The decoding process of the QR code.

3. **Application in the Field of Education.** QR codes are widely used in education. This section presents key educational applications, including teaching, assisted learning, library services, and attendance management. These examples show how the QR code increases accessibility, engagement, and efficiency in education.

**a. QR Codes in Teaching**

QR codes are applied in teaching work and are embedded in English classes [5, 43]. Teachers utilize QR codes to augment classroom practices [44]. Bala et al. propose an application for computer hardware courses using the QR code and augmented reality [45]. QR codes are used to achieve a digital education system [46]. QR codes for the music classroom are proposed by [47]. Rabu et al. utilize the QR code to support large classroom instruction [48]. The use of QR code technology in science classes is proposed by [49]. AlNajdi designs a new education system using the QR code in student textbooks [50]. QR codes are used to achieve the development of teaching [51]. A QR code-based student worksheet is developed for classroom use by [52]. Patil et al. utilize QR codes for resource management in higher education [53]. QR codes are used as an educational tool in physics classrooms by [6]. The development of QR code-based textbooks is proposed by [54]. QR codes are widely used in teaching to enhance classroom instruction across various subjects, including English, science, music, and physics. They enable interactive learning, digital resource access, and efficient educational management.

QR codes can assist in textbook development and support teachers in project-based instruction. Their increasing use in classrooms contributes to educational advancement, improves student academic performance, and is expected to be further adopted by more researchers in teaching applications in the future.

**b. QR Codes in Assisted Learning**

In assisted learning, QR codes empower students with mobile learning capabilities [7] and enable new learning developments [55]. They facilitate vocabulary acquisition in primary schools as shown by Yunus et al. [56], and spark interest in physical education through Rihatno et al.'s interactive e-book [57]. Maulidya et al. [58] introduce insectarium media with QR code features. Enhanced interaction is a goal of Hernando et al.'s usable application [59]. Rompegading et al. [60] create course modules based on QR codes, while Hidayat et al. [61] leverage movement card media. Hybrid learning models, such as those combining Google Sites and QR codes, have been used to improve students' understanding of multiplication [62]. Furthermore, Celik [8] finds QR codes helpful in improving pronunciation and vocabulary acquisition. By supporting mobile learning, enabling digital resources, and fostering hybrid approaches, QR codes effectively boost engagement and outcomes across a variety of educational subjects.

Moving from assisted learning, QR codes continue to support learning accessibility and student outcomes. Their integration benefits educational development, has a positive societal impact, and is likely to inspire further innovations.

**c. QR Codes in Library Services**

QR codes are used in libraries to enhance services. They have been applied to bibliographic records to facilitate quick access to resources [63]. The central library implements the QR code to improve user experience [64]. The use of QR codes in libraries is proposed by [10]. Din et al. design a new library

management system based on the QR code to streamline operations [65]. QR codes are applied for marketing academic libraries to increase visibility and engagement [66]. Kharat et al. propose a self-issue/return system for library materials using the QR code [67]. Based on the technology of QR codes, mathematics smartbooks are developed to support interactive learning [11]. The QR code is widely used in libraries to enhance services, streamline management, and support interactive learning.

Following their use in library management, it is important to recognize the broader educational role of libraries. Libraries have always preserved cultural and intellectual heritage, but traditional ones face challenges in information accessibility. As society advances, QR codes help libraries evolve to better serve students, further boosting educational improvements.

**d. QR Codes for Student Attendance**

Teachers utilize QR codes to manage student attendance [68, 69]. Deugo uses the QR code for attendance tracking [70]. Masalha et al. propose a QR code-based system displayed to students before lectures [71]. A smart student attendance system using QR codes is designed by [72]. Syahputra et al. propose a student attendance application using the QR code on student ID cards [73]. A web-based QR code is used to develop an absence information system [74]. Rahayua et al. propose a new online academic attendance system based on QR codes [75]. The QR code is widely used in student attendance systems, offering an efficient, automated, and reliable solution for tracking participation in educational settings.

Student attendance is crucial in the classroom, and taking attendance manually can waste a lot of time. If student attendance cannot be ensured, their learning cannot be guaranteed, leading to a decrease in educational quality. QR codes can be used for student attendance, saving time for teachers and helping to ensure student attendance.

**e. Summary**

QR codes have become popular in daily life and are increasingly applied in education. They are now widely used in teaching, assisted learning, library services, and student attendance. The QR code provides convenience for students to access educational content and enables teachers to conduct classroom activities more efficiently. Students can obtain textbooks, engage in mobile learning, and enhance vocabulary and interactive learning through QR codes, making assisted learning more accessible. In libraries, the QR code simplifies access to bibliographic records, supports book borrowing and returning, and helps modernize library management systems, keeping them up to date. Since regular attendance is crucial for effective learning, QR codes offer a time-saving solution for teachers to manage attendance, ensuring better student participation. As illustrated in Figure 5, the integration of the QR code across various educational fields enhances the efficiency of knowledge delivery and acquisition, benefiting both students and educators. With their proven advantages, QR codes are expected to be adopted in even more areas of education in the future.

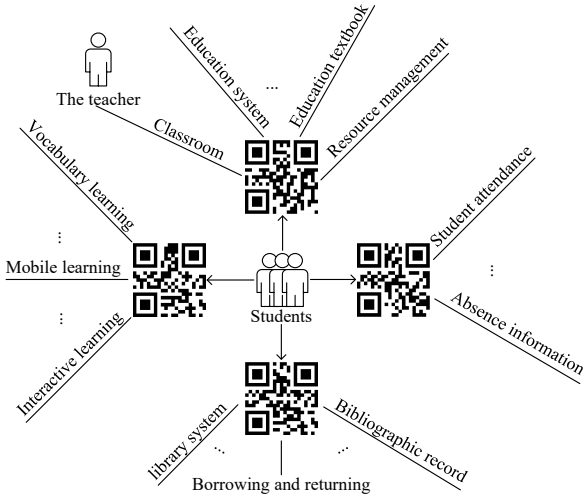


FIGURE 5. Application in the field of education using the QR code.

QR codes are widely used in daily life and are now transforming education. Their integration enhances teaching efficiency and expands student access to resources. This section highlights key educational fields currently using QR codes. As adoption grows, research will focus on optimizing QR code integration to further improve educational quality and effectiveness.

4. **Application in the Commercial Activity.** This Section explains how QR codes are used in commercial activities such as shopping, product information, mobile payments, tourism, and employee attendance.

**a. QR Codes in Retail and Hospitality**

QR codes enhance shopping. Irina et al. use QR codes to improve the shopping experience [15]. Demir discusses mobile marketing with QR codes [76]. Ozturkcan et al. design a QR code menu for hospitality as a sustainable solution [16]. Instead of using traditional menus, consumers order conveniently with QR code menus, which increases spending at restaurants [77]. Thus, QR codes make shopping and dining more convenient, enable marketing, and improve operational efficiency.

Using QR codes in retail and hospitality allows consumers to easily place orders and engage with products, encouraging consumption and supporting economic and social growth. QR codes will continue to integrate into business, creating seamless, personalized, contactless experiences while driving efficiency and digital transformation.

**b. QR Codes for Product Traceability**

QR codes help users quickly access product information. Jagodić et al. design a system that uses QR codes for object identification [17]. Picard uses QR codes to detect counterfeits [78]. Dey et al. digitize food production information for better accessibility, traceability, and verification [79]. Consumers scan QR codes to get product details [80], boosting confidence and comfort. Syam et al. [81] developed a QR-based inventory management system. Bhatia et al. [18] and Li et al. [82] use QR codes to track food origins. QR codes enable traceability, anti-counterfeiting, efficient inventory, and food tracking.

QR codes let producers manage products more easily and allow consumers to trace them. This builds consumer confidence and helps businesses thrive. Adding QR codes to product information improves commercial activities. In the future, QR codes will integrate with advanced technology to further improve traceability, consumer trust, and supply chain efficiency, connecting physical goods with the digital world for safer, sustainable commerce.

**c. QR Codes for Mobile Payments**

QR codes power mobile payments. Surekha et al. use them for secure e-tickets [19]. Khan et al. propose a Bitcoin wallet with QR code [83]. Fong et al. show QR code payments on smart city buses [84]. Alhafi et al. discuss e-payment and transactions [85]. Studies explore dynamic QR codes for payments [86]. Kumar et al. suggest a QR code vending machine [20]. These examples show QR codes offer safe, convenient payments in transport, retail, and digital transactions.

QR code mobile payments will become more common in smart cities, enabling seamless, secure transactions in transport, retail, and public services. As technology advances, QR codes will help build cashless societies and expand digital financial access, making payments easier for more people.

**d. QR Codes in Tourism**

QR codes improve tourism [87, 88]. Tourists use QR code payments [89]. Marwanl et al. use QR codes for communication and guidance [21]. Visitors scan QR codes for tourist information [22]. QR codes enable mobile payments, instant info access, and serve as interactive guides in tourism.

QR codes will play a central role in smart tourism platforms, delivering seamless, personalized, contactless experiences for visitors. They will boost engagement with automated guidance, real-time info, and integrated payments, driving more sustainable and tech-based tourism.

**e. QR Codes for Attendance Management**

Manual employee attendance tracking takes time, but QR codes offer efficient online tracking [90]. Alfiah et al. design a QR code attendance system [91]. Employees scan QR codes to log attendance on mobile devices [92]. QR codes with GPS improve accuracy [93]. Nwabuwe et al. use QR codes for fraud prevention [94]. These systems provide businesses efficient, accurate, and secure attendance tracking.

QR code attendance systems will become more advanced and connect with HR platforms to simplify workforce management. This progress will improve data accuracy, real-time oversight, and advance digital business operations.

**f. Summary**

QR codes are now common and strengthen commercial activities. QR code menus and mobile marketing enhance the shopping experience. Object identification, product traceability, and robust information systems allow consumers to check product details confidently. QR codes modernize payments with e-tickets, Bitcoin wallets, and vending machines. In tourism, QR codes streamline payments, guide visitors, and support digital platforms. For workforce management, QR codes simplify employee attendance and improve supervision efficiency. These examples show QR codes promote convenience, security, and efficiency in commercial areas, driving development, as shown in Figure 6.

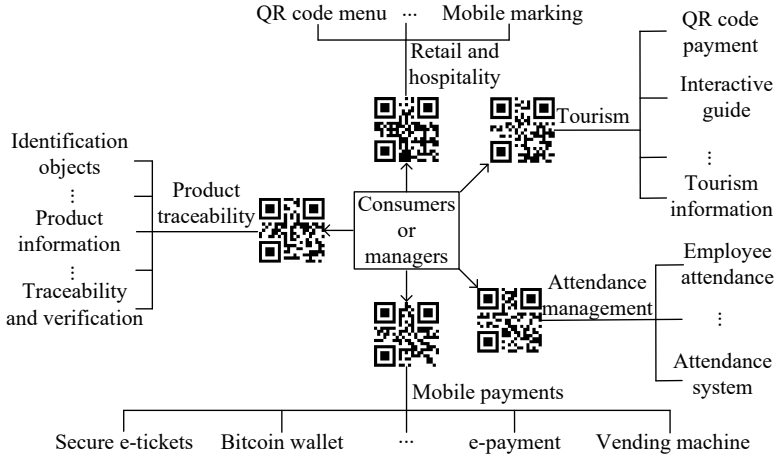


FIGURE 6. Application in the field of commercial activities using QR codes.

Using QR codes makes it easier for managers to manage goods and other operations. The QR code can enhance the shopping experience, making it more convenient and appealing for consumers, especially with the integration of mobile payments. This improved convenience leads to greater consumer satisfaction and encourages more frequent shopping. All of these benefits contribute to the growth of commercial activities and support broader societal development. In the future, researchers will apply QR codes more widely in commerce and explore their use in diverse fields to further drive commercial innovation and progress.

5. **Application in Information Security.** The QR code has gained popularity because it offers convenience and fast decoding speed. In information security, organizations primarily use it for encryption, authentication, SS scheme, and information hiding. QR codes enhance information security by protecting data integrity and enabling secure access.

**a. QR Codes in Encryption**

QR codes are utilized in encryption. Zhao et al. propose the optical encryption method based on computational ghost imaging with the QR codes [25]. Jiao et al. utilize a QR code-based noise-free method to achieve high-quality decrypted images [95]. An encryption model using QR codes is designed by [96]. Alyousif et al. use the QR code to enhance the locality of the encryption algorithm [26]. Various advanced cryptographic methods harness QR codes for robust, high-quality data protection.

Encryption algorithms are combined with QR codes to enhance information security. In the future, QR codes are anticipated to be used more widely in encryption and information security.

**b. QR Codes for Authentication**

QR codes are widely used for authentication, providing a convenient, time-saving method for verifying authenticity. They help authenticate academic certificates [27], enable two-level document authentication [97], and support embedded authentication information with ECCs [98]. Additional applications include access control [31], blockchain-based certificate authentication [99], smart security systems [32], individual identification [100], part authentication [101], document authentication with digital signatures [102], public transport tracking [103], and wireless security [104]. Integration with technologies like blockchain and digital signatures enables fast, secure authentication across diverse applications.

Combined with authentication systems, QR codes save time and increase convenience. They are used for authenticating documents, access control, certificates, products, and security applications, streamlining verification and improving efficiency. Growing adoption will further enhance security and user experience.

**c. QR Codes in Secret Sharing scheme**

The integration of QR codes with SS schemes has evolved through several research efforts. Wang et al. discuss the enhancement of security using QR code-based SS schemes [105]. Chow et al. extend these ideas by applying ECCs, designing QR code-based $(k,\ n)$-threshold SS schemes [106, 107]. Lin further introduces cheater detection and prevention with QR codes [29]. Subsequent research by Tan et al. explores using QR codes for sharing secret images [108], while Pan et al. employ color QR codes for sharing color images and introduce new color SS schemes [30, 109]. Applications have expanded to secure

document authentication [28], consolidating the roles of QR code-based SS schemes in secure, robust sharing, cheater detection, color image sharing, and document verification.

QR codes enhance SS schemes used for securing images. Serving as meaningful carriers, they reduce suspicion compared to meaningless images and improve stealth. Their integration strengthens overall security and robustness. Future QR code-based SS schemes will leverage advanced cryptographic techniques and AI for broader and smarter data protection.

**d. QR Codes in Information Hiding**

QR codes are used in information hiding, including steganography, watermarking, and data hiding. For steganography, methods include frequency domain [110], cryptographic schemes [111], encrypted messaging [112], and blind techniques [113]. In watermarking, approaches involve blind watermarking for attack detection [114], DCT/DWT techniques [115], YCbCr color space [116], and DOI embedding for copyright [117]. For data hiding, QR codes are used for message hiding [33], high-payload concealment [118], and LSB methods [34]. These techniques enhance security and copyright protection.

QR codes enhance the performance of information hiding techniques such as steganography, watermarking, and data hiding by improving quality, security, and payload. Future research will further advance QR code-based methods for efficient data protection.

**e. Summary**

QR codes are used in information security mainly in encryption, secret sharing, authentication, and information hiding. They help construct encrypted models, share secret images, enable authentication for various systems, and support watermarking, steganography, and data hiding (see Figure 7). These four areas are a subset of current uses. QR codes will continue expanding into more security domains, enhancing data protection.

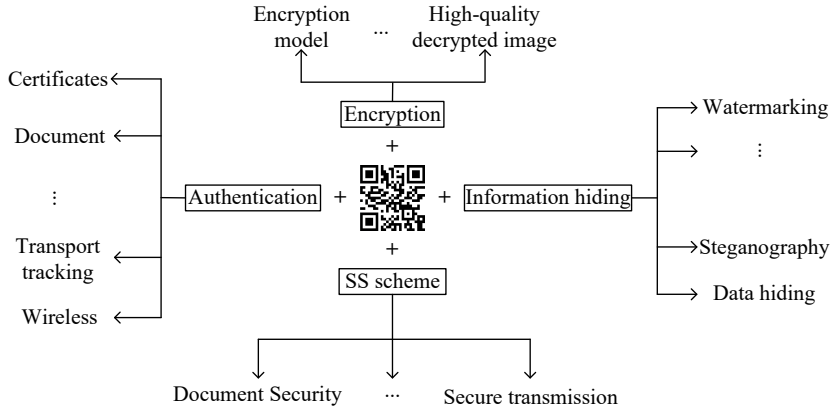


FIGURE 7. Application in the information security using QR codes.

The QR code is popular because of its fast decoding speed and convenience. It enables quick recognition by standard decoders. These characteristics make it well-suited for applications in information security. Integrating QR codes with information security technologies enhances overall system security. In encryption, QR codes can improve the security of encryption models and the quality of decrypted images. When combined with SS schemes, QR codes enhance security. They reduce suspicion from attackers by serving as meaningful shares and simplify share management for both senders and receivers. In authentication, QR codes increase verification speed and improve user convenience. In information hiding, QR codes help enhance security, increase data payload, and improve image quality in steganography, watermarking, and data hiding. The application of QR codes brings significant benefits to various aspects of information security. In the future, researchers will continue to expand their use into more domains within the field.

6. **Application in Accessing and Obtaining Information.** QR codes conveniently transmit information and play a key role in accessing and retrieving data. Organizations primarily integrate QR codes into four areas of information access: conveying information, locating resources, healthcare applications, and information management systems.

**a. QR Codes for Information Delivery**

QR codes are widely used for conveying information. Lorenzi et al. develop a digital government system using the QR code [35]. People can obtain various types of information from them. A system

for providing species-related information using QR codes is proposed by [119]. Jouini et al. design a traffic sign recognition system using QR codes [120]. A new data transmission method using QR codes is designed by [121]. Jiang et al. propose recognizing room numbers using YOLOv5 and QR codes [36]. Tirtasari et al. obtain plankton length information using QR codes [122]. Based on QR codes, a multi-level information access system is developed for wearable devices [123]. Applications include digital government, species identification, traffic systems, smart environments, and wearable devices, all of which enable efficient data dissemination.

Conveying information with QR codes is designed to save time. They transmit details about species, room numbers, data, and traffic signs, making access easier and faster. In the future, QR codes will be increasingly integrated into smart systems and IoT environments for more intelligent and context-aware information delivery across many domains.

**b. QR Codes for Smart Positioning**

QR codes are used for location acquisition. Eken et al. develop a smart bus tracking system using QR codes, saving travel time [37]. Idrees et al. propose an indoor navigation application for visually impaired users [124]. Zhang et al. use QR codes for mobile robot navigation [125]. Wang et al. propose robot navigation with RFID and QR codes [126]. Nazemzadeh et al. improve positioning accuracy by fusing QR code data with dead reckoning [127]. Smart traceability is achieved with QR codes [128]. Bach et al. correct localization errors via QR codes and encoder values [38]. Applications include public transit tracking, indoor navigation, and robot localization, enhancing positioning accuracy and operational efficiency.

QR codes aid location acquisition, letting machines obtain location information quickly and accurately. Integration with location-based systems includes smart bus tracking, mobile robot navigation, blind navigation, and localization error correction. In the future, QR codes will be key for intelligent positioning, enabling accurate, real-time, energy-efficient location services in smart cities, autonomous robots, and assistive technologies.

**c. QR Codes in Healthcare**

QR codes have been used in the medical field [129]. Czuszynski et al. enable medical data interaction with QR codes [39]. Uzun et al. develop a QR code-based medical identification system [130]. Jamu et al. utilize QR codes to support multi-professional learning [131]. A hospital information system using QR codes is designed in [132]. QR codes serve as electronic certificates [133], updating health status in real time. Belhan et al. employ them for opinion surveys in nursing education [134]. Nursahidin proposes a system to improve health clinic services [135]. Lai et al. use QR codes for teaching forensic DNA genotyping [40]. A mobile app for health data collection uses QR codes [136]. Applications include data interaction, patient identification, information management, education, and clinic services, enabling efficient real-time healthcare solutions.

QR codes facilitate communication between patients and healthcare providers. Medical students acquire professional knowledge through QR-based learning. Additionally, QR codes gather health and medical information efficiently. In the future, adoption will expand across medicine, enhancing data access, patient care, and education.

**d. QR Codes for Information Management** Information systems are developed using QR codes. Hidayanti et al. propose a library system [137]. Prasad et al. design a general information system [41]. Adnan develops a digital document management system [138]. Fuady et al. create a livestock management system [139]. Royani et al. propose a freight management system [42]. Applications include efficient tracking and management in libraries, documents, livestock, and logistics.

QR codes streamline information management systems, providing a convenient solution. Users simply scan to log in and perform tasks, saving time. In the future, integration will increase in management domains, further streamlining processes and enhancing convenience.

**e. Summary**

QR codes have been widely applied in accessing and obtaining information, as shown in Figure 8. They enable users to quickly retrieve species information, data, room numbers, and traffic sign details. In information management, the QR code can be used for information systems, document management, and logistics tracking. Location-based services support tracking, navigation, and positioning for applications such as smart transportation and robotics. In healthcare, QR codes facilitate access to medical data, patient identification, nursing education, and hospital management systems. With their convenience, efficiency, and versatility, QR codes can be integrated into numerous domains of information access, enhancing data availability and user experience across diverse fields.

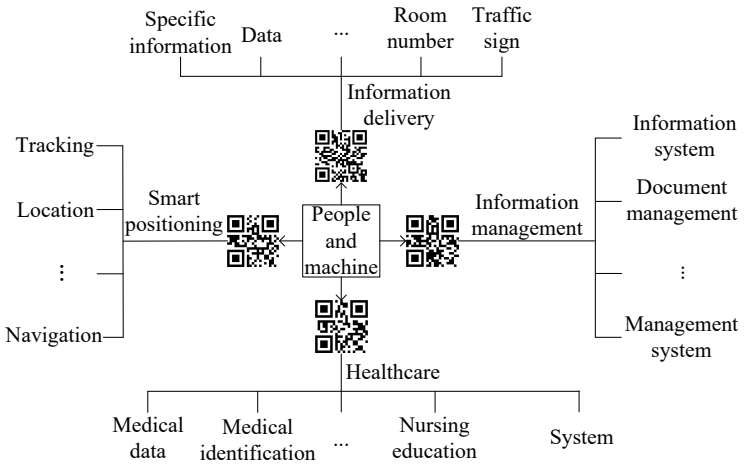


FIGURE 8. Application in the accessing and obtaining information using QR codes.

Integrating QR codes with information access helps save time and improve efficiency. Some information, like traffic signs or species details, is hard for machines to interpret. QR codes offer a machine-readable link to digital content. This approach simplifies data acquisition and enhances access to information. In the future, QR code integration will become more widespread, extending to new domains and advancing smart, connected systems.

7. **Conclusion and Future.** QR codes have become essential in modern life. Their fast decoding speed and user-friendly nature make them valuable tools. The widespread use of smartphones enables quick, intuitive QR code scanning and easy digital access. This paper explores how QR codes enhance efficiency and accessibility in education, commerce, information security, and information access. In education, QR codes boost learning by simplifying instruction and providing instant resource access. They support new teaching methods. In commerce, QR codes streamline shopping. Shoppers can retrieve product details and make payments instantly, which adds convenience and supports business growth. In information security, QR codes can join cryptographic methods. This hides sensitive data in plain sight and improves secure transmission. QR codes also allow rapid information retrieval. Users and machines can easily get data from traffic signs, documents, or identifiers, simplifying data acquisition. QR codes are now key to daily life, offering practical solutions across sectors. As their use in digital systems grows, QR codes will pave the way for smarter, more seamless connectivity.

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