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8. INNOVATIVE APPROACHES TO AUTOMATING ACCESS CONTROL SYSTEMS USING QR TECHNOLOGIES

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Annotation. This scientific paper describes the general idea of what innovative approaches to automation of access control systems using QR technologies are. The advantages of using such systems are presented, as well as applications that allow generating and scanning QR codes for access control.

Keywords. QR code access control, mobile access control, secure authentication, digital key systems, dynamic QR codes.

Information technology has become an integral part of people's lives. They are rapidly taking up a place in various fields of activity. The QR code system is no exception. The uniqueness of QR codes lies in a unique pattern that stores various kinds of information, including the user's personal data. Data encryption allows you to verify a large flow of information in less time. QR codes are two-dimensional barcodes organised in a matrix consisting of many square elements. Special markers placed in the three corners of the code allow scanning devices to quickly determine its position, size, and orientation.

QR code-based access control systems offer several advantages over traditional access control systems, including [1]:

1. Security: QR codes are unique to each user and cannot be easily duplicated, making them more secure than traditional access control methods.

2. Convenience: Users do not need to carry physical keys or cards, making the system more convenient to use.

3. Cost-Effective: QR Code-based access control systems are more cost-effective than traditional access control systems as they do not require the use of physical keys or smart cards. The only requirement is a smartphone or other mobile device with a QR code scanner.

4. Easy to Use: QR code-based access control systems are easy to use as they do not require any physical keys or smart cards. Users can access the facility or a specific area within the facility by simply scanning the QR code using their smartphone or other mobile device.

5. Increased Security: QR code-based access control systems are more secure than traditional access control systems as they use advanced encryption techniques. The QR code contains encrypted information about the user's identity and access level, which makes it difficult for unauthorised persons to gain access to the facility or a specific area within the facility.

6. Flexibility: QR code-based access control systems are more flexible than traditional access control systems as they can be easily integrated with other security systems, such as CCTV cameras and alarms.

7. Remote Access: QR code-based access control systems can be used to provide remote access to authorised personnel. For example, if an employee needs to access a specific area within the facility outside working hours, they can do so by scanning the QR code using their smartphone or other mobile device.

QR code scanning technology has evolved significantly, offering a range of devices tailored for various industries and use cases. These devices vary in size, functionality, and connectivity options, ensuring seamless data capture and processing. As businesses and organisations increasingly rely on digital transformation, QR code scanners have become essential tools for streamlining operations, enhancing security, and improving customer experience.

By leveraging QR code technology, companies can optimise workflows, reduce errors, and facilitate faster transactions, making these scanning solutions indispensable in modern business environments. Below there are several types of QR code scanners and their features, which came to different operational environment [2]:

1.Handy scanners. Hand-held scanners, also known as handy scanners, are portable devices that offer flexibility and ease of use. They are commonly used in retail, logistics, and warehousing industries due to their mobility and efficiency. These scanners read QR codes and transfer the data to a connected PC or similar device via cables or radio signals. They are available in various models that differ in reading distance, resolution, and durability, making them suitable for a wide range of applications. These scanners are lightweight, compact, and built to withstand demanding environments. Their versatility allows them to be used in various fields, including inventory management, package tracking, and point-of-sale transactions.

2.Handy terminals.Handy terminals are advanced information processing devices that not only read QR codes but also store and process the captured data. These devices can operate on different operating systems,

such as Windows CE, manufacturer-specific OS, and other custom software platforms. Due to their capability to store and analyse data, they are highly adaptable and can be configured for multiple applications depending on the installed software and their communication capabilities. Handy terminals are widely used in industries where real-time data processing and transmission are crucial, such as transportation, healthcare, and large-scale retail operations. Their ability to function independently from external processing units makes them invaluable in environments that require quick and efficient data management without relying on constant PC connectivity.

3.Fixed scanners.Fixed scanners, designed for stationary use, are often placed on desktops or embedded within other devices for automated scanning processes. These scanners process the captured data by transmitting it to a connected PC or similar system via wired connections. Fixed scanners are commonly embedded in admission gates, production lines, self-service kiosks, and vending machines to streamline automated workflows.

Beyond industrial applications, these scanners are frequently used in commercial environments such as retail stores, event venues, and transportation hubs, where they efficiently read QR codes on coupons, tickets, and boarding passes. Their integration into access control systems enhances security, while their implementation in automated checkout solutions improves transaction speed and customer convenience. The growing adoption of fixed scanners highlights their importance in reducing human intervention and increasing operational efficiency across multiple sectors.

As QR code scanning technology continues to advance, the range of available devices expands to meet the needs of different industries. From handheld and wearable solutions to fixed-mount and embedded scanners, each type offers unique advantages that enhance workflow automation, security, and data management. The evolution of these devices ensures their ongoing relevance in a wide array of applications, making QR code scanning an indispensable technology in modern business operations.

With continuous advancements in AI-powered recognition, enhanced scanning speeds, and improved data encryption, QR code scanning technology is poised to become even more versatile. As industries continue to embrace digital transformation, the integration of these solutions will play a crucial role in optimising workflows, reducing human error, and ensuring seamless connectivity across various platforms.

Currently, there are several solutions on the market for entering a room using QR codes. These systems provide a convenient and secure way to manage access, reducing the need for physical keys or access cards. They are widely used in hotels, office buildings, and event spaces, offering a seamless check-in experience for guests and employees.

Additionally, QR code entry systems can integrate with digital platforms, allowing administrators to track usage, grant temporary access, and enhance overall security:

1. QRPassport – is an application that allows you to enter office premises using QR codes. Using this **QRPassport** is an application that enables access to office premises through QR codes. This system facilitates visit logging and tracks the time spent in the office, allowing for the calculation of wages based on attendance data. Users can register independently, while managers oversee attendance on-site. The application is compatible with both Android and iOS operating systems, making it accessible on various electronic devices for office entry. A notable example of its implementation is **Alfa-Bank**, where employees register via the app on their devices and utilise a turnstile system to access office spaces.

2. Invixium – dynamic QR codes offered by Invixium are designed for visitors, and no visitor is the same. QR codes can be created for people with different security clearance, length of visit, and more. The dynamic nature of Invixium QR codes reduces all of these risks while minimising plastic waste. All data captured is only shared between each individual and business. Data is communicated using high encryption standards to ensure user and organisation privacy as well as security from hacking or data theft [3].

3. ButterflyMX – is the leading solution for enabling seamless access. What is more, ButterflyMX key fobs and virtual key codes are encrypted. Software product offers access control systems that allow residents and visitors to use QR codes on their smartphones for quick and secure access. So it is not necessary to worry about unauthorised users hacking or copying credentials. The ButterflyMX video intercom empowers you to visually verify visitors before letting them in. Moreover, it has a state-of-the-art 156° wide-angle camera that provides a clear view of visitors with minimal blind spots [4].

4. QR-Gate – is a system that controls access to any QR codes. The system allows you to read the QR code not only electronically, but also on a printed one, which allows employees to choose and not use their electronic devices. The system is designed for office space with very high traffic of people. This is how the system perceives artistic creation as 'space'. This system allows you to monitor visitors to your exhibitions.

There are also dynamic QR codes that significantly increase the level of security due to the fact that they are updated after a set time interval and thus prevent forgeries. Unlike statistical QR codes, which can be copied and reused, dynamic ones become irrelevant after a set time. Such QR codes can significantly improve the protection of access control systems in offices, residential complexes and facilities with high security requirements.

QR technologies are an innovative approach to the automation of access control systems, which makes it possible to strengthen the organisations protection by encrypting information and reducing the risk of unauthorised access. Creating unique and secure QR codes is essential for ensuring data integrity and protecting users from potential threats. Various methods and best practices can be applied to generate QR codes that are not only functional but also secure and trustworthy:

1. Using Reputable QR Code Generators It is crucial to choose established and reputable QR code generators that provide features like customisation, error correction, and tracking. These tools ensure that QR codes are unique and that the links embedded in them lead to secure destinations. Well-known generators offer a level of security that prevents users from being redirected to malicious sites, thus making them a safer option for businesses and individuals alike [5].

2. Implementing Secure Design Features. Incorporating secure design features into QR codes can also enhance both their functionality and security. For instance, adding a company logo or custom shapes to the QR code can create a visual identity while ensuring the code remains scannable. However, it is important that these aesthetic elements do not interfere with the code's readability. Some platforms offer advanced tools to create custom QR codes while maintaining high levels of security and scannability [6].

3. Utilising Dynamic QR Codes. Dynamic QR codes are a particularly useful option for creating secure and flexible QR codes. Unlike static QR codes, dynamic codes can be edited after they are created, which makes it possible to update the destination URL or embedded data without changing the code itself. This feature helps businesses manage their QR codes efficiently, making them ideal for use in marketing campaigns, product tracking, and more. Additionally, dynamic QR codes can be tracked, providing insights into user interactions and allowing companies to detect and respond to any security threats [6].

4. Applying Security Measures. To further enhance the security of QR codes, security features like Single Sign-On (SSO) and Multi-Factor Authentication (MFA) can be integrated into the websites or applications that QR codes link to. This additional layer of protection ensures that even if a malicious actor tries to exploit a QR code, they will not be able to access sensitive data without the proper authentication. Additionally, QR code generators that provide encryption for the data embedded in the codes can prevent interception during transmission, ensuring that the information remains secure [7].

5. Customising Domains and URLs. Using customised domains and unique URL slugs in QR codes is another method for improving both the trustworthiness and security of the codes. Custom domains help establish brand identity and encourage users to trust the source of the QR code. Furthermore, this approach helps protect users from potentially harmful links that may appear suspicious. By using branded or custom URLs, businesses can ensure that users are less likely to encounter phishing attempts or malware [8].

6. Following Best Practices for Distribution. When distributing QR codes, especially in public spaces, it is important to provide clear instructions and context so that users understand the purpose of scanning the code and feel confident in doing so. Best practices for QR code distribution include ensuring that the codes are easily accessible, visible, and placed in trusted locations.

Businesses and organisations should also educate their users about potential risks, such as scams, and encourage them to check for signs of suspicious behavior before scanning. This is particularly important in environments where QR codes might be placed in high-traffic areas or on public-facing materials like flyers or posters [9].

In conclusion, it is necessary to mention that the integration of QR technology into access control systems is a significant step forward in how enterprises and organizations manage user security and access. Offering an efficient, scalable and secure alternative to traditional methods, QR codes are an innovative solution that can be easily implemented and adapted to different environments.

The flexibility of QR codes, combined with the ability to personalise and enhance security measures with features such as dynamic codes and encryption, allows organisations to tailor their access control systems to specific needs. This adaptability makes QR codes a valuable tool in modern security infrastructures.

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