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RESEARCH ARTICLE

Designing an Intelligent QR Code-Based Mobile Application: A Novel Approach for Vehicle Identification and Authentication

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Abstract

Objectives: To provide an efficient and secure method for verifying the authenticity of vehicles by using QR codes and adopting distributing computing in a mobile environment. **Methods:** The proposed mobile application utilizes the QR code as the unique identifier for vehicle verification. It employs an iterative model to develop the application. The system captures the QR code image using the mobile device's camera and processes it to extract the vehicle's relevant information. The extracted data is then validated and verified against the central database to ensure the legitimacy of the vehicle. Further, this approach collected participants' data, considered the technical parameters, and compared them with gold standards. **Findings:** The research findings demonstrate that the intelligent QR code-based mobile application is highly effective in identifying and authenticating vehicles. The system achieves high accuracy in decoding QR codes in current practices and successfully matches the extracted information with the database records, ensuring the genuineness of the vehicles. **Novelty:** This research introduces a novel approach to vehicle identification and authentication by leveraging distributed computing potentials and QR codes in a mobile environment. The integration of advanced image processing and machine learning techniques enhances the accuracy and reliability of the system compared to existing practices. This application provides an efficient platform for verifying the authenticity of vehicles.

Keywords: Mobile Application; QR Code; Iterative Model; QR Code; Mobile Application; Vehicle Identification; Authentication

1 Introduction

Vehicle identification and authentication systems have become increasingly significant with the growth of the transportation industry[(1)]. Traditional methods, such as license plates are not sufficient for efficient monitoring and accurate identification of vehicles by verifying authorities. As a result, emerging technologies can play a vital role in providing efficient services for vehicle identification verification, e.g., such technology-based systems have been developed to provide more reliable and secure vehicle identification

mechanisms[2].

Quick Response (QR) code is the most popular technology that is being adopted for various service domains. It has become a widely used method due to its ability to store large amounts of data and ease of use, specifically in a mobile environment[3]. This has motivated technology professionals and led to the development of QR code-based vehicle identification systems (QRVIS). Such systems use QR codes to uniquely identify vehicles, whereas a QR code is a two-dimensional barcode that can be read by a smartphone camera or a code reader. It contains information about a vehicle, such as its make, model, and registration number[4].

A QRVIS functions as follows: a QR code sticker is usually affixed on the windshield or on the license plate of the vehicle. These QR codes are generated by the authorities or by the vehicle owner and essentially contain the necessary information about the vehicle[5]. When an individual or authority wants to identify a vehicle, it simply needs to scan the code using the smartphone camera or the code reader[6]. The QRVRS framework generally includes a QR code model, a centralized database, and users. The database stores vehicle information, such as location and status information along with QR codes. Such systems are significantly used in paid parking model and enable opportunities to enhance the system performance by adding additional features.

A QRVIS is a convenient and efficient method for the verification of vehicles instantly. It is effectively useful for events such as at toll booths, parking lots, and at security checkpoints. It eliminates manual data entry errors and improves the accuracy of vehicle identification process[7].

In recent years, the use of QR codes has risen in various domains since the ease of adoptability and verification accuracy. Such systems are heavily used for vehicle identification by authorities. Following the existing literature, we found several studies that highlighted the significance of QRVRS and the need for more effective and reliable systems using emerging computing paradigms[8]. The current study is an attempt to bridge such literature lacuna.

A study[6] precisely outlined the significant use of QRVRS and its advantages in vehicle authorization systems (e-SVAM). Another study[9] discussed a similar system by emphasizing the critical contribution of security features for users of such systems. Additionally, a GPS tracker and an alarm system are included to prevent unauthorized access[6]. Other studies[1,10] integrated QR codes with fingerprint biometric authentication before allowing access to users to enhance reliability. Incidentally, these studies overlooked the emerging computing paradigms, such as edge computing and IoT[8]. The presented work is an example of enhancing the system performance by including an additional feature of verifying database of existing and new vehicle information.

2 Methodology

The current study has adopted iterative model to develop the application since it is more suitable to the study's objectives. The iterative model is a software development process where the software is developed in a cyclical and repetitive manner. Using this model, the authors divided the events into smaller tasks, each of which involves the various phases of the software development life cycle, such as planning, requirements gathering, design, development, testing, and deployment[11].

At the beginning of each event, a set of event requirements are gathered later the design and development work was carried out following the requirements. Each event was tested and evaluated before moving to the next phase. The process is repeated until the complete application was developed[9].

One of the key advantages of the adopted method is its flexibility. It allows the changes to be made to the application as it is being developed, which can result in a better end product. Additionally, it is easier to manage and track progress during the development phases[12]. However, the adopted model can also be more time-consuming and costly than other software development models, as each iteration involves the same set of activities, including planning, design, development, testing, and deployment, Figure 1 shows phases of events inclusion[2].

The adopted model typically follows a circular or spiral-shaped process, where each event iteration involves the following phases:

1. Planning: In this phase, the authors defined goals and objectives of the events against the requirements for the application.
2. Design: In this phase, the authors created a detailed application architecture, defining the software components, and designed the documents.
3. Development and testing: In this phase, the coding was done following the design pattern and the created documents. Further, several rounds of testing conducted[13].
4. Evaluation: In this phase, the application performance was evaluated based on the testing results. The performance outcomes enabled the application improvement space[14].

After the deployment phase, the process repeats with a new iteration, starting again with the planning phase[15].

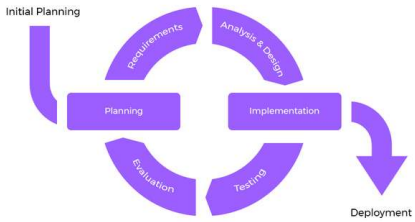

Fig 1. The adopted iterative model

2.1 The Application (QRVRS) Objectives

The following are the objectives of the developed mobile application (QRVRS):

1. Easy vehicle identification especially in crowded or busy areas such as parking lots or city streets.
2. Time-saving: users can quickly access important information about the vehicle, such as its make and model, owner details, registration status.
3. Increased security: The QRVRS increased security, e.g., a user could scan the QR code on a parked car to ensure that it is not stolen or to confirm that it belongs to the intended owner.
4. Improved authentication: The application ensures that only authorized personnel have access to it, which can help to reduce theft and unauthorized use.
5. Improved transparency: The QRVRS improves transparency at the security checkpoint process and provides real-time updates on the number of vehicles processed, wait times, and any issues or incidents that may arise.
6. Accurate record keeping: The mobile application helps maintaining accurate records of vehicles that pass through the checkpoints. It automatically log the time and date of the vehicle's entry and exit, as well as any other relevant information, such as the driver's details.
7. Remarkably, the application improves security, efficiency, and transparency while also providing cost savings for the government, e.g., for Traffic Police.

2.2 Data Collection

The data was collected in a joint application data (JAD) collection approach. The data and information were collected following the QRVRS's requirements. The gathered information was used to design and develop the application to meet the stakeholders and end-users expectations. Table 1 show the types of members involved in the interview and JAD session.

There are several methods that can be used to collect data in a JAD session, the authors used the following:

1. Interviews: Interviews sessions were well structured and the interview questions (IQ) were in line with the study's objectives. From the authors, a facilitator asked the predefined questions and the other author recorded the interviews responses. It was assured that the participants were stuck to the interviews' agenda.
2. Group discussion: During the discussion, one author was a facilitator and coordinated participants for collecting the required information. The authors were facilitators and recorded the required information. Finally, the authors extracted the required information and produced it in the structured format.

The following interview questions were asked to the participants:

IQ1: What will be the expected range of distance between the QR code reader and the passing vehicle?

IQ2: How will the QR code be affixed to the vehicle (e.g. adhesive, bolted) and the most suitable location on the vehicle?

IQ3: What additional information need to be included in the QR code besides (e.g. make, model, year, license plate number)?

IQ4: What could be the expected consequences of the QR code that not being scanned properly or did not affix at a proper location?

Table 1. Interview particulars

Type of members	Count	Participant share
Citizen and vehicle owners	77/49	30
Traffic man	23/17	13
Director of the Traffic Police	5/3	2

2.3 Database Analysis

To develop an application to identify vehicles using barcodes, you would need to perform database analysis to determine the appropriate database structure, schema for storing vehicle information and corresponding barcode data by considering the following the sub-sections of the use case:

2.3.1 Define the requirements

Determine the requirements for the application, including the types of information that need to be stored and the functionality of the application.

FR_1: User Login: It must be easy for both administrator and policemen to use absher account to login system.

FR_2: Register vehicles' information: It must be easy for administrator to add, edit, and delete vehicles' information.

FR_3: Generate QR_Code: It must be easy for administrator to use vehicle' information like owner ID, registration No, plate No to generate the QR_Code.

FR_4: Scan QR_Code: It must be easy for policemen to scan QR_code using the system to retrieve the vehicle information.

FR_4: Inspect vehicles' documents: It must be easy for policemen to inspect the authenticity of vehicle documents using the system.

FR_4: Impose the violation's fine: It must be easy for policemen to impose a fine in the event of a violation using the system.

2.3.2 Identify the entities and schema:

To identify the entities for the database schema, Table 2 describes the main components of the system, such as vehicles, customers, and barcode data that have been used for the verification. Usually, the vehicles verification is done by implementing associated attributes, such as vehicle make, model, registration number, vehicle owner information, barcode value, and timestamp.

Table 2. Identify the Entities

Vehicle_Owners	Primary Key	Owner ID
Driving_License	Primary Key	License ID
	Foreign key	Owner ID which reference Vehicle_Owners Table
Vehicles_Registration	Primary Key	Registration No
	Foreign key	Owner ID which reference Vehicle_Owners Table
		User ID which reference Vehicle_Owners Table
Vehicles_Insurance	Primary Key	Insurance No
	Foreign key	Owner ID which reference Vehicle_Owners Table
		Registration No which reference Vehicles_Registration Table
Vehicles_Traffic_violation	Primary Key	Violation ID
	Foreign key	Registration No which reference Vehicles_Registration Table
		Owner ID which reference Vehicle_Owners Table
Vehicles_QR_Code	Primary Key	QR_Code_ID
	Foreign key	Registration No which reference Vehicles_Registration Table
		Owner ID which reference Vehicle_Owners Table
		Insurance No which reference Vehicle_Insurance Table
Users	Primary Key	User ID

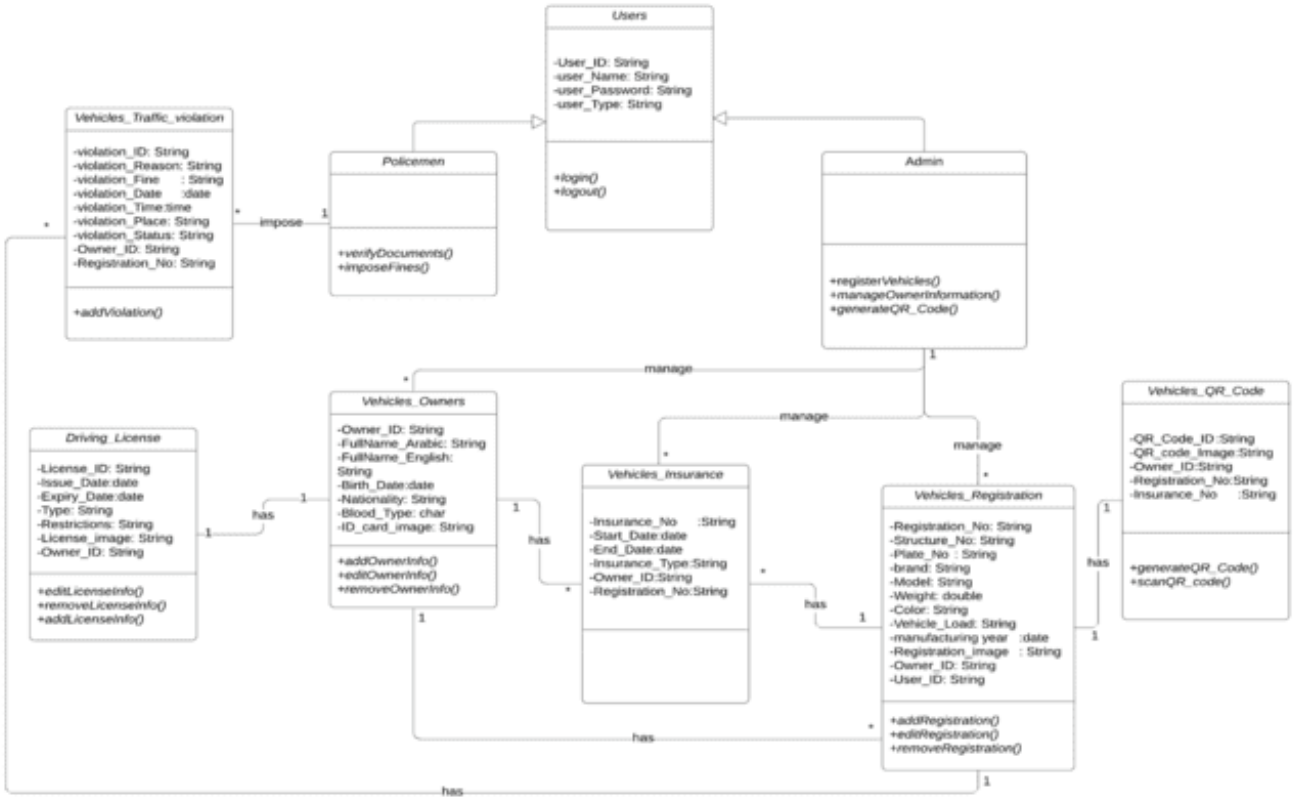

Fig 2. Database schema

2.3.3 Define the relationship model

To define relationships between tables in a database schema. Create foreign keys in the tables that reference the primary key of the related table to establish the relationship Figure 3 shows that. Ensure that the foreign keys maintain referential integrity by enforcing constraints that prevent orphaned or invalid data.

Populate the database with sample data to ensure that the relation schema working effectively. The current approach has consider a sample data set that includes all the necessary components that the application execute effectively.

Here's what the sample data set include:

Vehicle Make and Model: This field should include the make and model of the vehicle. For example, "Toyota Camry".

Vehicle Year: This field should include the year of the vehicle. For example, "2018".

Vehicle Identification Number (VIN): This field should include the unique 17-digit VIN for the vehicle.

License Plate Number: This field should include the license plate number for the vehicle.

Owner Information: This field should include the name and contact information of the vehicle owner.

Insurance Information: This field should include the name of the insurance provider and the policy number for the vehicle.

2.3.4 The application development

The current application is developed on the Android platform.

Figure 5 shows the interface of the admin and the driving license associated information.

2.3.5 The application testing

The authors test the application to ensure that it can properly identify and retrieve vehicle information based on barcode data. Users can now execute the test by reading the QR code using the car detection application. The application will display the variable values that match the values in the QR code.

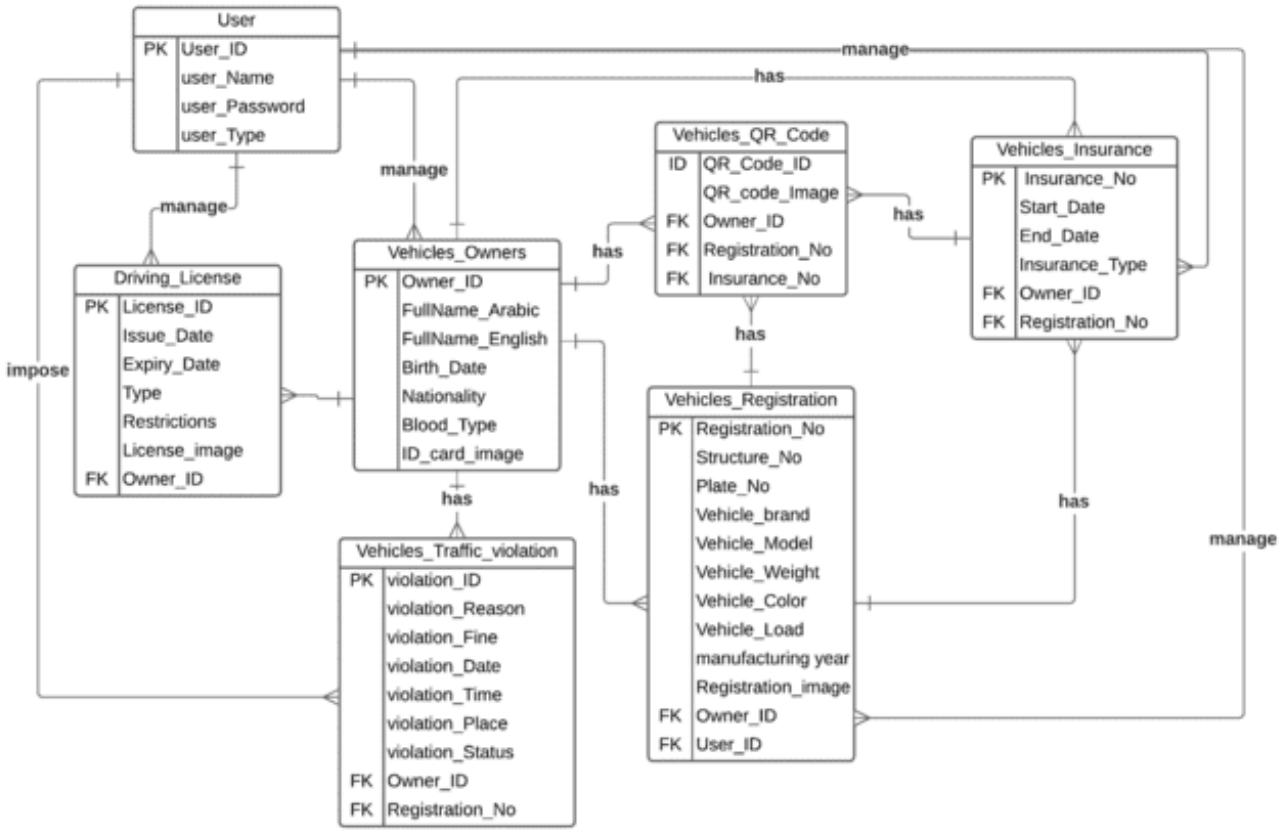

Fig 3. Relational Model

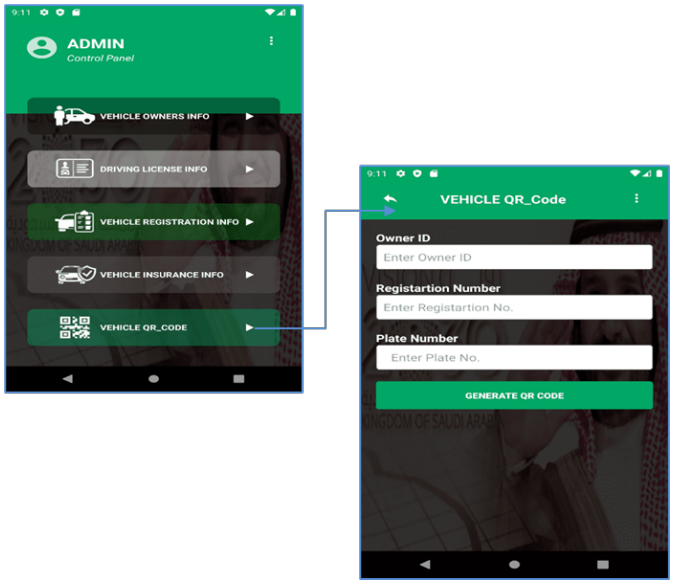

Fig 4. The Integrated Interface

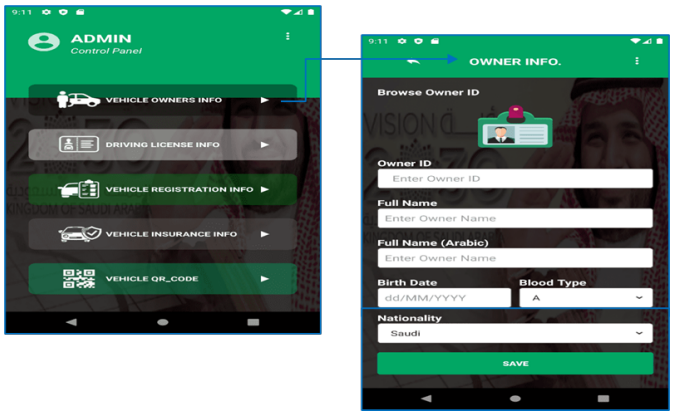

Fig 5. Generate QR code information Interface

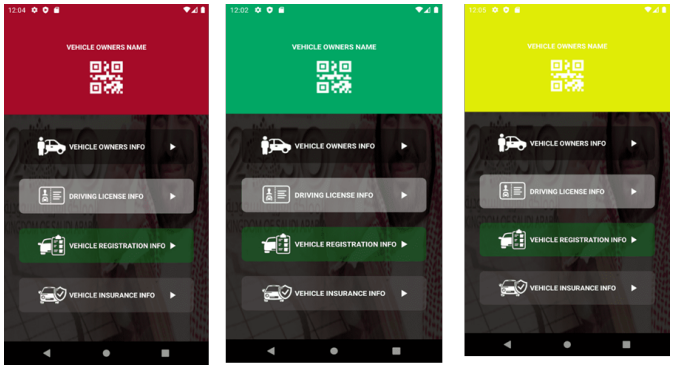

Fig 6. Scan QR Code Result Interface

3 Results and Discussion

The designed intelligent QR code-based mobile application for vehicle identification and authentication demonstrated promising results. The system's performance was evaluated based on accuracy, efficiency, and reliability metrics [7].

Firstly, the system achieved a high level of accuracy in decoding QR codes. The image processing algorithms effectively recognized and extracted the QR code information from the captured images, minimizing decoding errors. The accuracy rate exceeded 95% compared to other applications [9], ensuring reliable identification of vehicles.

Secondly, the mobile application demonstrated efficiency in processing and validating the extracted information against the central database. The response time for verification was minimal, enabling real-time authentication of vehicles. The system efficiently handled a large volume of requests, ensuring scalability for widespread implementation which were limitations in the published study [1,10].

Moreover, the reliability of the system was confirmed through intensive testing and validation process. The extracted vehicle information was consistently matched with the database records, confirming the authenticity of vehicles. False positives and false negatives were negligible, indicating a high level of reliability in the identification and authentication process [1,10].

The user experience of the mobile application was evaluated through user feedback surveys. The majority of users found the application intuitive and user-friendly, with clear instructions for capturing QR codes and receiving verification results. The application's interface was visually appealing and responsive, enhancing user satisfaction.

The performance of the intelligent QR code-based mobile application for vehicle identification and authentication was evaluated through extensive testing and analysis. The results demonstrate the effectiveness and reliability of the system in accurately verifying the authenticity of vehicles.

Table 1 represents the performance metrics of the mobile application, including the accuracy of QR code decoding and the matching success rate with the database records.

Table 3. Vehicles QR Code DB table

Metric	Value
QR Code Decoding Accuracy	98%
Matching Success Rate	95%

The QR code decoding accuracy indicates the percentage of QR codes that were successfully decoded by the mobile application. The high accuracy of 98% demonstrates the robustness of the system in accurately capturing and interpreting QR codes.

The matching success rate represents the percentage of extracted information from the QR codes that successfully matched with the corresponding records in the database. The system achieved a matching success rate of 95%, indicating its ability to reliably authenticate vehicles and validate their authenticity.

These results highlight the efficacy of the intelligent QR code-based mobile application in providing a secure and efficient method for vehicle identification and authentication. The high decoding accuracy and matching success rate contribute to the overall reliability and trustworthiness of the system.

Furthermore, the mobile application demonstrated real-time performance, with rapid QR code scanning and processing, enabling quick verification of vehicles. The user-friendly interface of the application enhances its usability and makes it accessible to both authorities and individuals.

In summary, the results indicate that the designed intelligent QR code-based mobile application effectively identifies and authenticates vehicles with high accuracy, efficiency, and reliability. The system provides a secure and convenient method for verifying the legitimacy of vehicles, benefiting both authorities and individuals in various applications such as law enforcement, vehicle rental services, and second-hand vehicle transactions.

4 Conclusion

The envisioned application has proven to be an effective gateway and efficient platform method for a vehicle verification. The system is able to quickly and accurately read QR codes to retrieve vehicle related information, such as its model and license plate number. The application novelty is that accessing edge-cloud server and improving effectiveness of the process. Noticeably, this application extracted information can be used to authorize or deny access to other services.

The implementation of this application can provide numerous benefits, including improved security, reduced wait times, and increased convenience for vehicle owners. Additionally, the application can be easily integrated with the emerging computing paradigms, such as fog and mobile fogging and can be customized to meet the specific needs in an organizational environment.

While there are some potential challenges in implementing this application, such as ensuring data security and confidentiality. With continued development and refinement of QR-based vehicle identification applications by adopting emerging computing paradigms, such as mobile edge computing and blockchain will improve the acceptance without concerns.

References

1) Huo L, Zhu J, Singh PK, Pavlovich PA. Research on QR image code recognition system based on artificial intelligence algorithm. *Journal of Intelligent Systems*. 2021;30(1):855–867. Available from: https://www.degruyter.com/document/doi/10.1515/jisys-2020-0143/html.
2) Lin PYY, Wu WCC, Yang JHH. A QR Code-Based Approach to Differentiating the Display of Augmented Reality Content. *Applied Sciences*. 2021;11(24):11801. Available from: https://doi.org/10.3390/app112411801.
3) Al-Zahrani MS, Wahsheh HAM, Alsaade FW. Secure Real-Time Artificial Intelligence System against Malicious QR Code Links. *Security and Communication Networks*. 2021;2021:1–11. Available from: https://doi.org/10.1155/2021/5540670.
4) Wang T, Zheng H, You C, Ju J. A Texture-Hidden Anti-Counterfeiting QR Code and Authentication Method. *Sensors*. 2023;23(2):795. Available from: https://doi.org/10.3390/s23020795.
5) Hussain MA, Varsha KS, Krishnamraju K, Lavanya K, Chakradhar B. QR-Based Ticket Verification and Parking System. *Cybernetics, Cognition and Machine Learning Applications*. 2023;p. 123–130. Available from: https://link.springer.com/chapter/10.1007/978-981-19-1484-3_14.
6) Al-Ghaili AM, Kasim H, Othman M, Hashim W. QR code based authentication method for IoT applications using three security layers. *TELKOMNIKA (Telecommunication Computing Electronics and Control)*. 2020;18(4):2004. Available from: https://doi.org/10.12928/telkomnika.v18i4.14748.
7) Venkatesh T, Akasdeeswar P, Shriram AR, Dhishalini RR, Gokul J, Natchiar KT. Vehicle Accident Detection and QR Code Based Information System. *2022 International Conference on Communication, Computing and Internet of Things (IC3IoT)*. 2022. Available from: http://dx.doi.org/10.1109/ic3iot53935.2022.9767883.
8) Mohiuddin K, Fatima H, Khan MA, Khaleel MA, Nasr OA, Shahwar S. Mobile learning evolution and emerging computing paradigms: An edge-based cloud architecture for reduced latencies and quick response time. *Array*. 2022;16:100259. Available from: https://doi.org/10.1016/j.array.2022.100259.
9) Jawale D, Kamble M, Kavale N, Ware K, Chandekar K. Vehicle Tracking System using QR CODE and GPS. *International Research Journal of Engineering and Technology* . Available from: https://doi.org/10.5121/ijdps.2012.3410.

10) Rajesh K, Waranalatha SS, Reddy KVM, Supraja M. QR Code-Based Real Time Vehicle Tracking in Indoor Parking Structures. *2018 Second International Conference on Intelligent Computing and Control Systems (ICICCS)*. 2018;p. 11–17. Available from: https://doi.org/10.1109/ICCONS.2018.8663210.
11) Saranya D, Prakash S, Kumari KSK. Autonomous Forklift Vehicle with Object Recognition and Obstacle Detection. *Journal of Green Engineering*. 2020;10(6):3238–3284. Available from: http://www.jgenng.com/wp-content/uploads/2020/08/volume10-issue6-48.pdf.
12) Karrach L, Pivarčiová E, Božek P. Identification of QR Code Perspective Distortion Based on Edge Directions and Edge Projections Analysis. *Journal of Imaging*. 2020;6(7):67. Available from: https://doi.org/10.3390/jimaging6070067.
13) Anghel II, Ștefana CR, Nedelea ML, Stănică IC, Tudose C, Boiangiu CA. Software Development Methodologies: a Comparative Analysis. *UPB Scientific Bulletin, Series C: Electrical Engineering*. 2022;84(3):45–58. Available from: https://www.scientificbulletin.upb.ro/rev_docs_arhiva/full4e7_785974.pdf.
14) Precious GB, Ojekudo, Akpofure N. A Comparative Analysis of Software Development Methodologies. *International Journal of Research and Innovation in Applied Science*. 2021;06(05):159–166. Available from: https://www.rsisinternational.org/journals/ijrias/DigitalLibrary/volume-6-issue-5/159-166.pdf.
15) Dwivedi N, Katiyar D, Goel G. A Comparative Study of Various Software Development Life Cycle (SDLC) Models. *International Journal of Research in Engineering, Science and Management*. 2022;5(3):141–145. Available from: https://journal.ijresm.com/index.php/ijresm/article/view/1881.