Automatic private parking system using license plate recognition and car make and model recognition

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***Abstract*— In this paper we purpose an automatic gate system for parking space entry with authenticity confirmation from 2 individual modules, car make and model and license plate detection. The vehicle detection sensor identifies when cars come to a halt in front of the gate, prompting the camera to snap images of them. The approach used to segment the images in license plate detection is connected component analysis. Connected regions indicate that all pixels sharing a connection are part of the same object or entity within the image. The algorithm for detecting car make and model utilizes feature extraction methods such as the Difference of Gaussians (DoG) detector and the Scale Invariant Feature Transform (SIFT) descriptor. These techniques help identify distinctive visual features of cars, enabling accurate recognition and classification. The Euclidean distance measure is employed to find the most suitable match between a query image and those stored in the database. This comparison aids in determining the car's make and model by assessing the similarity of visual features extracted from both the query and database images. In the final stage, matching algorithms are applied to decide whether the output of the LPR and make and model detection does not conflict with the details stored in database. Access to a parking lot is granted only when specific conditions are met.**

Keywords—license plate detection and recognition, make and model, SIFT

I. INTRODUCTION

Ensuring security is paramount, particularly for accessing restricted premises. Surveillance cameras play a pivotal role by capturing digital records of individuals and vehicles entering the area. Leveraging computer vision and image processing techniques, these images and videos can be automatically analyzed. With the escalating number of vehicles, such technologies offer expedited and efficient solutions to manage security effectively.

Automatic license plate recognition (ANPR) systems have emerged as valuable technology for identifying traffic violations and exerting some control over them. Moreover, they offer added advantages such as theft prevention, access control management, and enhancing overall safety for both individuals and vehicles. ANPR systems have become ubiquitous in various public spaces like parks, shopping malls, and more, contributing to enhanced security and management. Indeed, while ANPR systems offer significant benefits, they may not always be foolproof in recognizing cars, especially in instances where forgery is possible. License plate forgery or alteration can undermine the accuracy of ANPR systems, potentially leading to misidentification or evasion of detection. As such, while ANPR technology is valuable, it's essential to complement it with additional security measures and verification techniques to mitigate the risks associated with forged or altered license plates [1]. Absolutely, relying solely on ANPR systems in high-security areas such as military compounds or governmental organizations poses risks due to the potential for license plate forgery or alteration. Integrating car make and model recognition with ANPR enhances security measures by adding an extra layer of verification. This combination not only strengthens security but also aids law enforcement agencies in investigating criminal activities involving vehicles. Additionally, in certain secure environments like airports or military installations, this technology can be employed to track employees movements, further bolstering security protocols.

In this work we purpose a smart private parking lot based on the functionalities of license plate and car make and model detection. Vehicle detection sensor is employed to detect when cars come to a stop at the gate. Following this detection, two subsequent modules capture the image of the car and conduct the necessary analysis. After extracting information such as the number plate, car make, and model, the system verifies entry by matching this data with details stored in a database. If there's a discrepancy or mismatch in the data, entry is denied as a security measure.

This paper is organized as follows: The second section describes related works, the third section introduced entry gate of the private parking lot, forth section describes purposed solution structure and the last section conclusion of the previously described work.

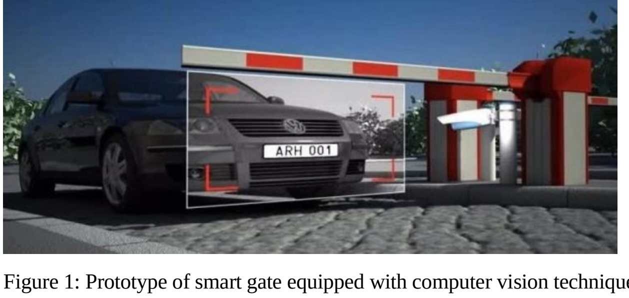

Figure 1: Prototype of smart gate equipped with computer vision techniques

II. RELATED WORK

Research in the field of Intelligent Transportation Systems (ITS) encompasses various techniques, including

Automatic License Plate Recognition (ANPR) and Automatic Vehicle Make and Model Recognition (AVMMR). These techniques play crucial roles in enhancing traffic management.

A. Automatic License Plate Recognition (ANPR)

The Scale Invariant Feature Transform (SIFT) is a powerful method for describing local image features, extensively utilized in various pattern recognition tasks [2]. Research, such as the work referenced in [3], often relies on SIFT features for their robustness and adaptability to scale and rotation changes in images. However, challenges such as background clutter, variations in illumination, and image blurring can significantly impact the recognition rate of SIFT-based methods. Overcoming these challenges remains a focal point in advancing the effectiveness of pattern recognition systems utilizing SIFT features. In [4], a novel approach utilizing the SIFT algorithm was proposed for license plate localization. This method identifies keypoint features in images, which are then utilized in the matching process between input images and character templates. Recognition is based on the distinct transition patterns among pixels of characters. These unique transition patterns sets of 60 Brazilian license plate images each demonstrated accuracies of 88.33% and 70%, showcasing the effectiveness of the proposed approach in license plate localization and recognition. In [5], a different approach employed a SIFT-based template matching technique for localizing Jordanian number plates. Following localization, Optical Character Recognition (OCR) was applied to recognize the characters within the segmented license plates. This combined approach leverages SIFT for accurate plate localization and OCR for character recognition, offering a comprehensive solution for number plate recognition in Jordanian contexts. In the license plate recognition method proposed by authors of [6], the initial step involves localizing blue color areas in the HSV color space. This method primarily targets the detection of standard Iranian plates. Color and geometric characteristics serve as cues for localizing license plates within the HSV image, which is divided into multiple blocks. Any tilts in the located license plate are addressed using pixel arrangement features, achieving successful detection even at angles of up to 45 degrees. In the character recognition stage, normal factoring with a similarity measure is applied, resulting in an impressive accuracy of 97%. In [7], ANPR system tailored for Indian license plates was developed, employing the template matching technique for character recognition. The segmentation stage proposes utilizing either rectangular projection of the number plate or an alternative template matching method. However, it's noted that testing was conducted on a very limited dataset consisting of only 8 images, encompassing variations in shape, illumination, view angle, distance, etc. This indicates the need for further evaluation and validation on a more extensive and diverse dataset to assess the system's robustness and generalizability.

In [8], the ANPR system employs Fourier transform to detect the inherent spatial frequency of characters in a license plate. After localizing the plates using Fourier analysis, characters are segmented based on connected components, and recognition is performed using Support Vector Machines (SVM). This approach utilizes Fourier analysis for effective plate localization and SVM for accurate character recognition, showcasing a comprehensive methodology for ANPR systems.

In [9], the license plate recognition task is tackled using the You Only Look Once (YOLO) deep learning framework. With 7 convolutional layers, the system achieves around 98.22% accuracy for license plate detection and 78% for recognition. Traditionally, ANPR systems were commonly implemented on PC-based platforms due to their processing power, enabling the handling of high-quality images within shorter timeframes. However, there's a growing trend towards considering mobile-based platforms for ANPR, indicating a shift towards more versatile and accessible solutions for automatic number plate recognition. Authors of this study [10] introduces a method leveraging a deep learning framework employing the YOLOv5 architecture to enhance car license plate recognition. To assess the efficacy of this approach, the researchers generated a custom dataset and conducted thorough experiments involving training, validation, and testing processes. This comprehensive evaluation allows for a robust assessment of the proposed method's performance and its potential for improving license plate recognition accuracy. Authors of [11] employed the YOLOv7 object detection model for effectively detecting vehicles, access badges, and license plates. Also, its adaptability allows it to be used in different countries by retraining the object recognition model to recognize the respective LPs, access badges. Despite its effectiveness, the Shine system has its limitations.

This paper [16] follows a systematic approach consisting of five steps for license plate extraction: image pre-processing, license plate location, background color recognition, character segmentation and character recognition. Using KNN like template matching technique they are recognizing Arabic number with high accuracy and makes the identification closer. They are archived a plate extraction and background color accuracy as 97.78%, Arabic number recognition with OCR as 45.56%, and with KNN as 92.22%.

B. Automatic Vehicle Make and Model Recognition (AVMMR)

Zafar et al.'s approach, as described in reference [12], presents a 2D Linear Discriminant Analysis (LDA) method for the recognition of car make and model. Their experimentation revealed that this approach outperformed Principal Component Analysis (PCA). This suggests that for the specific task of car make and model recognition, the 2D LDA method yielded superior results compared to PCA. In reference [13], a hierarchical classifier was introduced, initially determining the class of the vehicle and then proceeding to recognize the make and model within a smaller group. Their algorithm achieved an impressive accuracy of 96% on a dataset consisting of over 280 back view images of vehicles. Additionally, the algorithm demonstrated robustness to various environmental conditions such as illumination and weather changes. This highlights its effectiveness in real-world scenarios where such conditions can significantly impact performance. In [14], vehicle model recognition leveraged the geometry and appearance of car emblems within rear-view images. They employed a linear

Support Vector Machine (SVM) binary classifier with Histogram of Oriented Gradients (HOG) features. Impressively, their approach achieved an accuracy of 93.75% on a dataset comprising 1342 images representing 8 car makes and 28 distinct car models. This underscores the effectiveness of utilizing emblem information for accurate vehicle model recognition, even amidst a diverse range of car makes and models. Authors of [15] purposes a new large-scale vehicle make and model recognition dataset, DVMM which covers the most popular cars available in Europe market. The DVMM dataset encompasses vehicle images with diverse colors, captured from various viewpoints, and under a multitude of conditions, including different camera types, image resolutions, illumination conditions, and background settings. To address the challenges posed by this variability, a novel deep-learning-based Vehicle Make and Model Recognition (VMMR) framework, termed 2B–2S, has been proposed. This framework adopts a two-branch processing approach and a two-stage network training strategy, aiming to enhance the model's robustness and accuracy across the wide range of conditions present in the DVMM dataset. The authors of [17], purposed a solution with a smart camera equipped with ANPR, AVMMR, and color recognition capabilities is described. Therefore, the make and model recognition component utilizes a Scalable Vocabulary Tree (SVT) constructed from Speeded Up Robust Feature (SURF) descriptors. SVT offers an efficient and scalable approach for recognizing vehicle makes and models based on these descriptors. In [18], the research delves into the efficacy of integrating various local feature point detectors with the SIFT descriptor. The study scrutinizes the performance of these combinations across four distinct databases. Through experimental analysis, the study reveals notably superior recognition rates achieved by the combinations of SIFT with Difference of Gaussians (SIFT-DoG), SIFT with Multiscale Hessian, and SIFT with Multiscale Harris. These findings highlight the effectiveness of these particular combinations in enhancing recognition accuracy across diverse datasets.

In paper [19], authors employed frontal view vehicle images and implemented a deep learning architecture based on SqueezeNet for the development of an AVMMR system. Through extensive experimentation conducted on a dataset comprising over 291,602 images encompassing 766 classes, the system achieved an impressive accuracy of 96.33%. This underscores the effectiveness of utilizing deep learning approaches, particularly the SqueezeNet architecture, for accurate and robust vehicle make and model recognition tasks, even when dealing with a large number of classes and diverse image variations.

The authors of this project [25] have developed a License Plate Recognition (LPR) system that achieves a high recognition rate without requiring high-quality video signals from expensive hardware. They also address the challenge of car make and model recognition, enabling the search of surveillance video archives using partial license plate numbers combined with visual descriptions of vehicles.

III. Entry gate of private parking lot

In [20], an automatic gate system was proposed to manage entry control at a building gate. This system operates on a patch-based matching process, where a segment of the incoming vehicle's image, referred to as a "patch," is compared with vehicle images stored in a database. This matching process enables the gate system to authenticate the identity of vehicles seeking entry by comparing their visual characteristics with those in the database. This approach ensures secure and efficient access control, allowing only authorized vehicles to enter the premises while preventing unauthorized access. The gate control system [21] utilizes the LPD information for giving staff permissions for campus entry. The authors of [22] developed an intelligent garage system which is uses the matching information of face recognition and license plate recognition to store and retrieve cars. In [23], the development of an automated gate system was observed to rely solely on license plate recognition (LPR) technology. In the system outlined in [24], a comprehensive approach is adopted, incorporating automatic license plate recognition (ALPR), vehicle make and model detection, and under vehicle inspection technologies. By combining these methods, the system aims to mitigate the limitations inherent in individual techniques and enhance security in vehicle inspection processes.

Combining license plate recognition with vehicle make and model recognition significantly bolsters security, enabling the creation of highly secure automatic gates at entrances to restricted areas such as private parking lots, airports, military bases, campus entries etc. This fusion enhances access control, improves security screening, streamlines management, and enables comprehensive monitoring of vehicle movements, ensuring heightened security and safety within the premises. The potential benefits of using purposed system are:

- Implementing screening procedures such as manual identity card checks can lead to reduced waiting times, also provides an opportunity to gather additional information about individuals entering the parking lot.
- Collecting statistical data regarding the types of visitors and the car models used provides valuable insights into parking lot usage.
- Categorizing incoming individuals, staff, and guests allows for efficient management of parking spaces by allocating appropriate slots for each category based on their specific needs and priorities.

IV. Solution structure

Purposed system structure is depicted in the Figure 2.

A. *Preprocessing phase*

Dataset of all registered cars is used in the implementation and testing of our prototype. In the preprocessing of real-time captured images, the initial steps involve converting the image to grayscale and removing noise through median filtering. Subsequently, binarization is applied, followed by connected component analysis, to identify target license plates based on their distinct structural properties (Figure 3). The process of extracting Regions of Interest (ROI) involves identifying specific areas around the headlights, upper and bottom grills of the vehicle. These regions encapsulate discriminative information crucial for recognizing car makes and models. An example of the selected ROI from a sample image is illustrated in Figure 4.

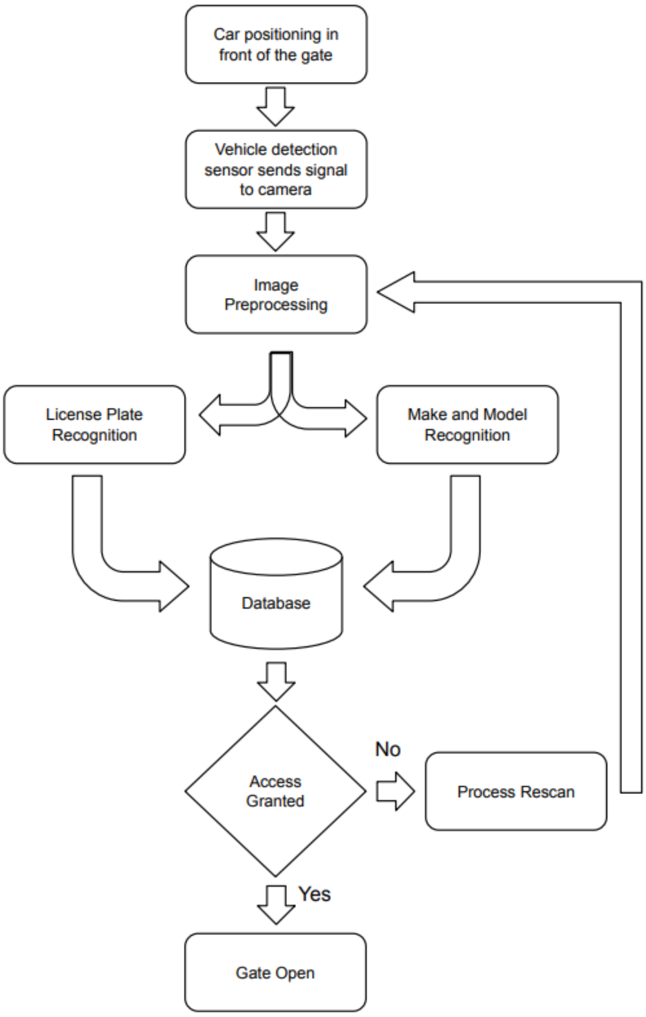

Figure 2: Purposed prototype of the parking lot system

Figure 3: License plate extracted

Figure 4: ROI representation for make and model recognition

B. *License Plate Recognition*

The segmentation of images employs Connected Component Analysis, where connected regions indicate that all connected pixels belong to the same object. Two pixels are considered connected if they share the same value and are adjacent to each other. This approach enables the identification of distinct objects or regions within the image based on their connectedness and pixel values. Output of the preprocessing phase, is provided as input to the next step and Connected Component Analysis (CCA) is applied on this image to bound the characters in plate. Once each character is identified during the character segmentation process, it is appended into a list. This list serves as a collection of individual characters extracted from the license plate image, facilitating further processing such as character recognition. Character extraction from the license plate is specifically tailored to read Macedonian formats. This entails designing methods are optimized for detecting and isolating characters present in Macedonian license plates. Customization ensures accurate and efficient recognition of sequence characters and numbers from Macedonian license plates, contributing to the overall effectiveness of the license plate recognition system.

C. *Make and Model Recognition*

The AVMMR system as described in [18] utilizes the following process:

- Detect interest points using DoG method.
- Extract SIFT descriptors from these keypoints.
- During training, compute SIFT features from images of various car make-models.
- Match query descriptors to prestored descriptors using Euclidean distance.
- Identify the best match based on the smallest distance, determining the make and model of the car.

Therefore, we made tests using the Stanford dataset, fine-tuning a ResNet-152 model specifically for European cars under various lighting conditions corresponding to different daily time slots. This dataset consists of 16,185 images representing 196 classes of cars. The data is split into 8,144 training images and 8,041 testing images, with each class roughly evenly distributed between the training and testing sets. This approach allows for comprehensive evaluation and validation of the model's performance across different lighting conditions and car classes, ensuring robustness and accuracy in car recognition tasks. We evaluated the recognition of 42 common make-model combinations found in both the dataset and the cars typically seen in Macedonia.

Table 1: Car make and number of models tested

Car Make	**Number of Models**
Audi	4
BMW	3
Mercedes	4
Skoda	4
Opel	5
Ford	3
Toyota	4
Kia	3
Fiat	2
Seat	3
Golf	4
Hyundai	3

The experiments were conducted using the samples listed in Table 1. The Region of Interest (ROI) was identified as the frontal area encompassing headlights and grills. Subsequently, all images were resized to maintain uniform dimensions. The outcomes of these experiments indicate that the best performance is observed when we are testing with the brightest images summarized in Table 2.

Since the system functions as a private parking lot, only authorized entities are permitted entry. Upon verification through LPR and cross-referencing with the database for car make and model, access is granted or denied based on credentials. If access is denied, the system allows three consecutive scans of the LPR and car make and model to mitigate potential weather deviation or system weakness. Following the third failed scan, a message will be displayed stating "Access denied for vehicle xxx with license plate yyy." (Figure 5).

Table 2: Accuracy depending on image lighting

	Accuracy (%)		
Car Make	**25% lighting**	**50% lighting**	**100% lighting**
Audi	65.32	67.17	69.09
BMW	66.45	68.3	70.22
Mercedes	66.85	68.7	70.62
Skoda	67.87	69.72	71.64
Opel	69.75	71.6	73.52
Ford	64.58	66.43	68.35
Toyota	63.24	65.09	67.01
Kia	67.54	69.39	71.31
Fiat	66.57	68.42	70.34
Seat	69.36	71.21	73.13
Golf	64.21	66.06	67.98
Hyundai	60.35	62.2	64.12

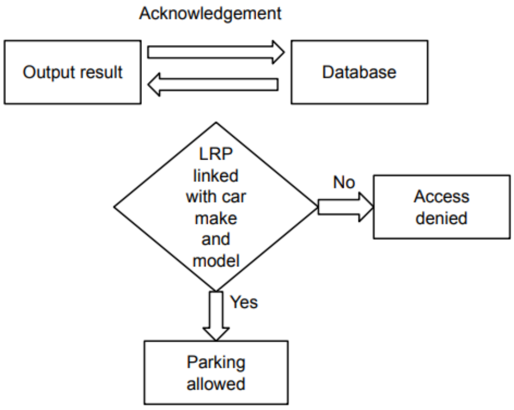

Figure 5: Car verification procedure

V. Conclusion

We introduced a real-time automatic gate system by integrating car make and model recognition with license plate recognition. Deploying such a gate can significantly reduce human effort and enhance security in the designated area. The expedited authentication process helps mitigate traffic congestion that may occur due to manual screening or the use of card readers.

Integrating car make and model recognition together with license plate recognition in private parking systems can ensure that only authorized vehicles are granted access. This helps in preventing unauthorized vehicles from entering restricted areas, enhancing overall security. That means significantly reducing the risk of spoofing attempts where individuals try to gain unauthorized access to a parking lot by transferring license plates to other vehicles. Because of that reasons we implement conditional check following license plate verification with the associated make and model of the vehicle. By making access conditional on both, the system becomes more resistant to spoofing attempts. Even if someone were to transfer a license plate to another vehicle, the mismatch between the make and model and the expected data would trigger an alert, preventing the system for unauthorized access.

Absolutely, this system can be readily adapted to high-security areas due to its robustness and effectiveness in controlling access and enhancing security measures. Whether it's international airports, military bases, government facilities, or other sensitive locations, the integration of car make and model recognition with license plate recognition offers a comprehensive and reliable solution for access control. Its ability to minimize human intervention while maximizing security makes it an ideal choice for safeguarding high-security areas.

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