Challenges in Automatic License Plate Recognition System Review

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***Abstract*— Nowadays, processing vehicle license plate data has become a common and challenging subject of research in Image Processing and Artificial Intelligence. There are various methods proposed to address this problem due to the different shapes and sizes of license plates in different countries. License plate recognition can be used for different purposes, including parking lots, public and private entrances, traffic monitoring systems, cargo control in airports or harbours, and security issues such as finding stolen cars. The technology for license plate recognition is known by different names, including automatic number-plate recognition, automatic vehicle identification, car license plate recognition, and optical character recognition for cars. This technology converts image data from a camera into a character format that can be processed in a database for specific applications. Optical character recognition methods can identify the characters on license plates with great accuracy. The main objective of this paper is to provide a systematic literature review of the most common challenges and methods used for optical character recognition in automated number plate recognition systems, as well as their level of recognition accuracy.**

Keywords—Deep learning, Computer vision, ANPR, OCR, OpenCV, External factors, Internal factors

I. INTRODUCTION

ALPR stands for Automatic License Plate Recognition, which is a technology used to automatically read and capture license plate information from vehicles. This technology typically involves cameras that capture images of license plates and specialized software that processes those images to extract the license plate information. ALPR systems can be used for a variety of applications, including parking management, tolling, law enforcement, and border control. With the advancement of technology, services in various aspects of life are also improving. One significant area where technology is playing a crucial role is the vehicle transport system. This system has a significant role to play in traffic monitoring, crime detection, tracking stolen vehicles, and other security applications [1]. The initial concept of an automatic license plate recognition system was developed by a UK police station [2]. Over the years, this technology has undergone hardware and software advancements, with a focus on improving its accuracy [3]. However, the system's current accuracy level is still not up to par with traffic requirements due to challenges such as poor lighting, a high number of plates, and unreadable plates.

Automatically License Plate Recognition (ALPR) is a technology that uses image processing to identify vehicles based on their license plates. It is essential for automated traffic monitoring and law enforcement on public roads. The article discusses an LPR algorithm for a smart parking system that uses images to automatically recognize license plates for entry. The system aims to improve accuracy by enhancing image quality, extracting license plate information, and isolating characters. If a car's license plate is admitted, the door will be automatically opened, and if not, it will remain closed [4].

Deep Learning has become an effective way to analyze large amounts of data through complex algorithms and artificial neural networks. Convolutional Neural Networks (CNNs), a type of artificial neural network, are commonly used for object and image recognition and classification. CNNs are used to identify objects in images by Deep Learning. CNNs play a critical role in various tasks, including image processing, localization and segmentation in computer vision, identifying obstacles in self-driving cars, video analysis, and natural language processing for speech recognition. As CNNs are widely used in these growing areas, they are popular in Deep Learning [5].

II. BACKGROUND OF STUDY

Machine learning, deep learning, artificial intelligence, and Internet of Things are being used to solve transportation issues like traffic congestion, parking difficulties, accidents, and safety. Smart solutions are needed to decrease these problems. Automated and intelligent electronic solutions have been developed in recent years.

[6] explains how to use artificial neural networks to create an automatic number plate recognition system for crowded areas and tollways. The system uses OpenCV, a programming library for real-time computer vision, to improve traffic flow and reduce congestion at tollways.

In [7] utilized template matching algorithm with normalized cross correlation and phase correlation method to test 90 patterns under different conditions. The paper compared the accuracy of normalized cross correlation method and phase correlation method in identifying license plates. The normalized cross correlation method achieved an accuracy of 67.98%.

In [8]. This article presents an algorithm for detecting number plates and identifying letters, which is based on a combined feature extraction model and BPNN. The algorithm achieves an efficiency of 97.7% and enhances time performance.

The article [9] discusses an automated parking fee calculation system that is capable of detecting 41 out of 50 THAI number plates with an accuracy rate of 93.42%. The system helps reduce manual identification of license plates. However, the accuracy of the system can reach 100% only if the number plates are bright, luminous, and free from noise.

The researchers developed a method to recognize license plates in images using deep neural networks. They processed the license plates and used LSTM Tesseract OCR Engine for

recognition, achieving a 99% precision with 95% LPR accuracy. They plan to increase the size of the image dataset in the future [10].

In [11], the authors describe an automatic gate control system based on license plate recognition to enhance security and convenience at important locations. The system uses a PIC microcontroller and a regular PC with a video camera to detect visible license plates and process them. The system operates automatically and can recognize license plates to allow or deny entry. The proposed system was implemented using MATLAB, Proteus, and Micro C, and achieved a recognition accuracy of about 98%.

The author of [12] suggested an optimal approach for the ALPR system for Bangladeshi vehicles using deep neural network models. They trained and evaluated these models on their datasets of Bangladeshi vehicles and license plates. They also introduced an algorithm that eliminates the need for the segmentation phase and generates output efficiently. The proposed system offers 99.37% accuracy in license plate localization and 96.31% accuracy in text recognition.

III. Automatic Number Plate Recognition

ANPR is an optical system that identifies car license plates from images. It is a crucial tool used for traffic management, security, parking, and speed control. ANPR is implemented in various areas such as parks, highways, by police, customs, and private companies [13]. It is possible to extract data about a driver with just one image. The quality of the acquired images is crucial for the ANPR system to function correctly. The system uses Optical Character Recognition (OCR) to recognize characters on number plates from images acquired by surveillance cameras. The number plate uniquely identifies a car and can only be extracted if the image is clear and not defective [14]. For accurate license plate recognition, it is important to position the camera at the right angle to capture a clear image. The characters on the license plate are analyzed individually using Optical Character Recognition (OCR). OCR is a technology used to convert written or printed text into digital format and is utilized in various fields such as business, industries, research, security, literature, and even medicine, to develop devices for individuals with visual impairments [15]. The ANPR system is commonly used for various applications, including recognizing plate numbers, passports at airports, barcodes in institutions, and handwritten text in electronic documents. The system has algorithms or rules for processing images and license plates, but there are challenges due to blur, insufficient lighting, objects obstructing the license plate's visibility, poor angles, different fonts, and inconsistencies between states [16].

IV. Style of Turkish License Plate

The vehicle number plate in Turkey is rectangular and made of aluminum with a white background and black or yellow font letters. On the left side of the plate, there is a blue bar with the country code "TR" in the size of 4x10 cm. Two plates are mandatory for all vehicles except for motorcycles and tractors, with one placed at the front and the other at the rear. The text format on the plates follows a pattern of either "00 X 0000", "00 X 00000", "00 XX 000", "00 XX 0000" or "00 XXX 00". The first two digits indicate the province code number of the car owner's residence [18].

V. Methodology and Challenges

Traffic rule violations are a major cause of accidents, and ALPR plays a significant role in restricting them, as well as being necessary for intelligent transportation systems. The ALPR system consists of four main parts, Below is a figure Fig. 1 that displays the minimum components required for an ANPR (Automatic Number Plate Recognition) system: image acquisition, license plate localization (LPL), character segmentation, and character recognition. The accuracy of each stage affects the overall accuracy of the system. The first part involves inputting high-resolution digital images of the car from the front and rear, followed by image processing techniques such as Gaussian and Prewitt filters to extract the license plate in the second part. In the third part, the characters and numbers in the extracted license plate are segmented, and finally, both ANNs and SVM are used for character recognition [19].

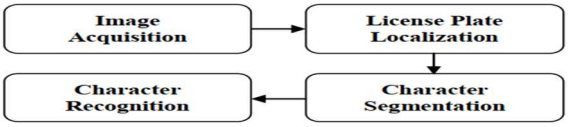

Fig. 1. Flow diagram of ALPR system

The ALPR system's accuracy and performance depend on its ability to handle different conditions at each stage. However, there are many challenges in the domain of the ALPR system that affect its accuracy and processing time. These challenges can be due to external or internal factors of the ALPR system [20]. The external factors can be classified into three categories:

- Plate variation
- Environmental variation
- Camera Mounting variation

The internal factors can be classified into two categories:

- Technique/Algorithm Used in ALPR system
- Hardware used in ALPR system

These factors will be discussed in detail in the following sections.

A- External Factors

1. Pate Variation

Plate size: The size of High Security Registration Plates (HSRP) or Turkish License Plates (LP) is standardized, but some people may use unstandardized LPs of varying sizes and dimensions, which can be seen in Fig. 2. Although unstandardized LPs are not allowed legally in Turkey, they do exist, presenting a challenge for the ALPR system to be able to handle this variation in plate size, Figure 2 displays license plates of different sizes [21].

Fig. 2. LPs with different plate sizes

Plate position: In Turkey, there are regulations for the placement of license plates on vehicles in terms of their horizontal and vertical positions and height from the ground.

However, in practice, license plates may be mounted anywhere on the vehicle, as illustrated in Figure 3. This presents a challenge for the ALPR system to accurately locate these plates [21].

Fig. 3. LP with different plate positions

Plate color: In Turkey, the HSRP has standardized colors for the background and text on the LP. However, in Turkey, LPs come in various color combinations. Private vehicles have black text on a white background, commercial vehicles have black text on a yellow background, rental vehicles have yellow text on vehicles have white text on a light blue background, and electric vehicles have white text on a green background. This variety of colors poses a challenge for the ALPR system to accurately recognize LPs, Figure 4 displays license number plates of various colors [22].

Fig. 4. LPs with different plate colors

Number of LPs in an Image: When you take a picture with a camera, you might see one or more license plates (LPs) in the picture, as shown in Figure 5. This can happen because of the camera's field of view or other reasons. It is also difficult for the automatic license plate recognition (ALPR) algorithm to detect and recognize all LPs and their registration numbers in the image [21].

Fig. 5. Number of plates in an image

Plate Character Font: HSRP has standardized the fonts used in license plates (LP), including character width, height, and stroke width, as stated in reference [7]. However, there are also license plates that are not standardized, as seen in Figure 6. This poses a challenge for the automatic license plate recognition (ALPR) system to locate the license plate and recognize characters with varying font parameters [23].

Fig. 6. LP with different fonts

Plate Occlusion: there is a lot of dust on internal or local roads, which can accumulate and stick to license plates (LP). This can cause the characters on the LP to become partially or fully invisible, as depicted in Figure 7. This makes it difficult for the automatic license plate recognition (ALPR) system to recognize characters from such images [24].

Fig. 7. LP with different plate occlusions

Noise: There are often noisy or unwanted components on license plates (LP) or the body of a vehicle, such as screws, frames, pipes, text-like structures, stickers, and stamps, as illustrated in Figure 8. This poses a challenge for the automatic license plate recognition (ALPR) system, which must avoid mistaking these components for part of the LP [25].

Fig. 8. LP with different noises

Physical Obstructions: License plates (LP) can have unwanted obstructions, such as frames, pipes, and ribbons, as demonstrated in Figure 9. These obstructions can partially or completely hide the LP, which presents a challenge for the automatic license plate recognition (ALPR) system to extract the characters from such LPs [26].

Fig. 9. LP with different physical obstruction

Damaged Plate: License plates (LP) can become partially damaged for various reasons, as illustrated in Figure 10. Additionally, the stroke of a character may be broken, making

it difficult for the automatic license plate recognition (ALPR) system to detect such LP and recognize its characters, Damaged License Plates (LP) are depicted in Figure 10 [26].

Fig. 10. Damaged LP

Skew: The skew of a license plate (LP) can be caused by incorrect mounting of the plate and band or by the curvature of the road. This presents a challenge for the automatic license plate recognition (ALPR) system to detect the LP from such images, Figure 11 displays the skew of a license plate (LP) [27].

Fig. 11. Skew LP

2. Environmental Variation

Lighting Conditions: Images taken by a camera can vary in lighting conditions depending on the time of day, including sunlight, evening, night, shadow, glare, and cloudy conditions, as illustrated in Figure 12. Furthermore, license plate images can be impacted by both one's own vehicle's headlights and those of other vehicles, which can pose a challenge for automatic license plate recognition (ALPR) systems [28].

Fig. 12. LP with different lighting conditions

Surrounding effects: Other patterns and textures, such as characters written on the background, that resemble the license plate can impact license plate detection, as shown in Figure 13 [28].

Fig. 13. LP with different surrounding effects

3. Camera Mounting Variation

The performance of the ALPR system can also be affected by the camera mounting technique, as mentioned in reference [10]. The camera can be either fixed or moving, with the former being mounted on a stationary surface and the latter being mounted on a moving surface, such as a patrolling vehicle. Relative velocity between the camera vehicle and the target vehicle can be a challenge for a moving ALPR camera. In most ALPR systems, fixed camera mounting is used, which cannot be mounted with zero horizontal and vertical angles [29].

Angle [11]: Three main parameters related to angle of Mounting of camera affects the accuracy of ALPR system as shown in Fig. 13.

Pan: The angle between LP and camera pan

Tilt: Elevation angle of the LP image

Projection Orientation: The angle at which LP is rotated left or right.

Fig. 14. Angle associated with camera mounted

The ALPR system may face issues depending on the angle between the camera and the plate axes. A high angle can make it difficult to detect and extract characters from the license plate.

Fig. 15. LP with different camera angles

Plate distance from camera: The performance of the ALPR system is affected by the distance between the license plate and the camera, as depicted in Figure 16. This poses a challenge for the ALPR system to be robust for varying distances between the camera and the license plate [29].

Fig. 16. LP with different distance from camera

Area ratio: To improve the ALPR system's accuracy, the camera must be positioned to focus mainly on the LP region, as illustrated in Figure 17, while minimizing the non-LP region captured [30].

Fig. 17. LP with different area ratio

B. Internal Factors

The ALPR system consists of both hardware and software components, and it's essential to choose the best combination of these two for optimal performance. The following are the primary internal factors that can impact the system's performance [31].

1. Technique/ Algorithm

Different algorithms have their limitations, such as requiring a specific processing time, which can be challenging to meet the real-time application requirements [32].

2. Hardware

Camera shuttering speed (Motion Blur): The speed of the vehicle and the camera's shutter speed [12] affect the amount of motion blur in the image. A larger shutter speed can reduce the open time and decrease motion blur, which presents a challenge for reducing motion blur in ALPR system [33].

Fig. 18. LP with different camera shuttering speed

Camera Resolution (Quality of Image): The resolution of the camera is a challenging factor for the ALPR system. Although high resolution can provide good image quality, it can also increase the overall processing time of the system. Fig.19 illustrates this issue by showing images with varying resolutions [33].

Fig. 19. LP with different camera resolution

Camera focus length (Maximum distance): The maximum distance between the camera and LP is determined by the camera's focus length, as demonstrated in Figure 20. Automatically adjusting the focus length for the ALPR system is also a challenge [34].

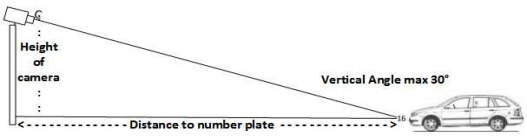

Fig. 20. Maximum distance and view angle between LP and camera

Camera view angle (Area of Interest): The camera's view angle, denoted as 'Φ' in figure 19, determines the area on the ground/road that is of interest. Adjusting or deciding the appropriate camera view angle is a challenging task for the ALPR system [35].

System internal RAM and Processor (Fast Processing): The internal RAM and processor specifications of the ALPR system are also crucial factors that can impact its performance and cost. Choosing the right specifications for both is also a challenging task [35,36].

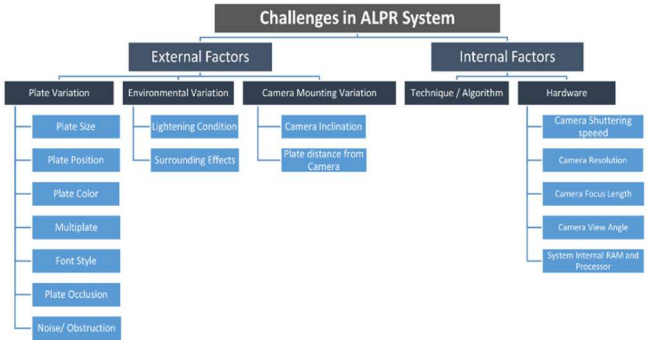

Fig. 21. Classification of different ALPR challenge

VI. Conclusion

This paper presents the challenges faced by the ALPR system, which can be categorized as external and internal factors. Fig. 21 shows the external factors as plate, environmental, and camera variations. Hardware and algorithm are the internal factors that also affect the ALPR system's performance. Overcoming these challenges is difficult, and most existing techniques only address a few of them. More research is needed to develop a robust ALPR system. This paper aims to help researchers in the ALPR system domain by providing an overview of the challenges and guiding them in defining their research goals.

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