Research Article

A Novel Approach for Automatic Car Plate Detection and Recognition

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Abstract

The increasing number of cars inside cities creates problems in traffic control. This issue can be solved by implementing a computer-based automatic system known as the Automatic Car Plate Recognition System (ACPRS). The main purpose of the current paper is to propose an automatic system to detect, extract, segment, and recognize the car plate numbers in the Kurdistan Region of Iraq (KRI). To do so, a frontal image of cars is captured and used as an input of the system. After applying the required pre-processing steps, the SURF descriptor is utilized to detect and extract the car plate from the whole input image. After segmentation of the extracted plate, an efficient projection-based technique is being exploited to describe the available digits and the city name of the registered car plate. The system is evaluated over 200 sample images, which are taken under various testing conditions. The best accuracy of the proposed system, under the controlled condition, shows the high performance and accuracy of the system which is 94%.

Keywords: Automatic Car Plate Recognition, SURF Descriptor, Segmentation, Character Recognition, Digit Recognition, Horizontal Projection, Vertical Projection.

1. Introduction

During the last decade, Image processing and computer vision have gained enormous attention from researchers from various fields of study such as medical, security, game, agriculture, etc. Traffic control (Davies *et al.*, 1990), car owner identification (Draghici, 1997), automatic toll collection (Lotufo *et al.*, 1990), Automatic vehicle parking system (Albiol *et al.*, 2011), etc. are among the dozen applications of image processing for which the car plate (license) should be automatically detected, extracted and recognized. Therefore, the Automatic Car Plate Recognition (ACPR) has become an interesting field of study among researchers in the literature.

The typical ACPR system gets a car plate (or car image which includes the car plate), as input and generates the combination of letters, digits, and words by which a car plate can be identified.

Besides the high speed and accuracy of ACPR systems, invariance to the light condition, rotation, and scale transformations are the decent features that an ideal system should be empowered with.

One of the main steps of any ACPR system is the accurate extraction of the car plates which is referred to as Car Plate Localization. The results of this step will be directly reflected in the next stages of the whole system for the recognition process.

The Car Plate Recognition step, on the other hand, is the core part of the system by which the extracted car plates should be segmented, described and recognized, correctly.

Several studies have postulated a direct relationship between the accuracy of the segmentation process and the recognition rate, so the better segmentation of the alphanumeric symbols of the plates, the more precise the car plate recognition result.

As will be shown in the next section, plenty of previous researches into ACPR have mainly focused on the recognition of the car plates, rather than the localization (Algainahi, 2011), that is, the input image of such systems is considered to be a manually-extracted well-aligned image of car plates.

In this paper, a fully automated novel approach of ACPR system is presented by which the car plates of the Kurdistan Region of Iraq will be detected, segmented, and recognized. The system acquires the frontal image of the vehicle, in different sizes and directions, and performs the preprocessing operations, then the required steps toward recognizing the car plate letters and digits will be applied.

The proposed system will perform both localization (detection) and recognition of the car plates at the same time. The plate's location will be detected from the frontal image of the car. Then, the extracted part will be passed to the recognition part of the system. This part will segment the available symbols and recognize them using an effective and efficient descriptor. A detailed description of the proposed system is presented in section 3.

The rest of this paper is organized as follows: the next section will briefly discuss some similar researches that have been conducted in the literature. Then, we will present a detailed description of the proposed system in section 3. Practical results of the simulated system will be shown in section 4. And finally, a summary of the main findings, together with the future works is provided in the last section.

2. Literature Review

Since the first appearance of ACPR systems in 1979 in Britain, the literature on automatic car plate recognition has highlighted several approaches to improve the accuracy and efficiency of such systems. Valuable surveys on the efforts done in the literature can be found in (Patel *et al.* 2013) and (Amatya & Sarvanan, 2017). Due to the closer relationship between the current work and the Arabic/Persian ACPR systems, this section is mainly dedicated to reviewing the techniques done in Iran and the Arabic countries.

An Iraqi ACPR system using a template matching approach has been proposed by Abbas and Hashem (2016). Their system includes two main phases: car plate detection and recognition. After the pre-processing stage, plate detection using Sobel edge detection is performed followed by the removal of undesired objects. On the other hand, the correlated template matching approach was used for recognizing the digits, letters, and words which resulted in 98.2% of accuracy.

Another Arabian ACPR system for Egyptian cars was proposed in 2013 (Massoud *et al.*, 2013). According to the authors' claim, unlike the other systems, their system gets video stream as input, but they have not clarified the process of selecting the appropriate frame. The car plates are extracted using Sobel edge detection followed by dilation, and erosion to locate the rectangular areas. Finally, the characters and digits have been described and recognized via the statistical cross-correlation approach. Under a controlled testing condition on 100 car plates, an accuracy rate of 91% has been achieved.

In a different work, the multi-resolution scheme along with Hidden Markov Model (HMM) have been leveraged for recognition of Arabic (Indian) digits (Awaidah & Mahmoud, 2009). The authors have followed a trial and error scheme to estimate the best size and states of the HMM. They used structural, gradient, and concavity as features of the numbers. The experiments on their dataset, having 21120 sample images show an average accuracy rate of 99%.

Ebrahimi *et al.* (2015) have recently introduced an ACPR system for the Iranian car plates. They have detected the car plates using the blue margins available for all typical Iranian car plates and used Support Vector Machine as an approach for the plate recognition. Their achievement rates were 90%, 95%, and 97% for plate detection, segmentation, and recognition, respectively.

To the best of our knowledge, there are only two research that has been conducted for ACPR in the Kurdistan Region of Iraq (Ali *et al.*, 2015) and (Wady *et al.,* 2017). Regardless of the common steps, they have followed, the main difference between their works is related to the descriptors they have leveraged; in the former study, the cluster of Gabor feature vectors along with Support Vector Machine and Neural Network were used for the feature extraction and recognition phase, while the Haar Wavelet transformation and a color histogram is the underlying descriptor in the latter one. As the result of evaluation under various illumination conditions, the best optimal accuracy of the Neural Network-based approach was 96.72%

Despite the availability of several studies and implemented ACPR systems, a gap still exists between the existing systems and the ideal ones. Accurate localizing of the plate under various viewing/ weather conditions is among the gaps which are being tackled in the current paper.

3. Proposed Approach

In this section the proposed ACPR system and its sub-systems will be described, a general view of the system is illustrated in Figure 1.

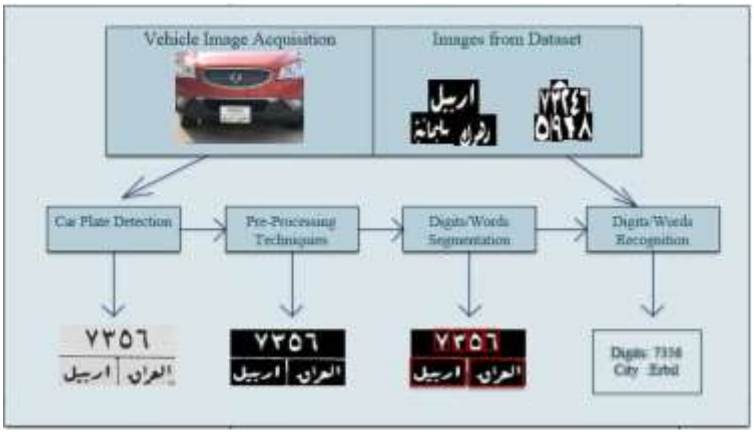


Figure 1. The Overview of the Proposed System.

3.1. Image Acquisition

Any ACPR system begins with the image acquisition step. This stage aims to capture the image of frontal view of the vehicle using a digital camera. The image also can be loaded from a pre-stored dataset of police stations. The images might differ in size, color, distance, angles and resolution depending on the utilized camera. Figure 2 shows a set of sample images that will be utilized as the input of the system.

Figure 2. A Set of Sample Images of Car Plates in the Kurdistan Region. (Note That the Plates Can Have a White, Yellow, or Red Background).

3.2. Image Pre-Processing

As mentioned before, the input image might have some variations in terms of size and alignment. Furthermore, the images might be degraded due to the presence of noise, low-resolution deficiency, etc. Therefore, the input images should go through several pre-processing operations such as resizing all images to 200*200 pixels, converting the color image into a grey scale and binary one, and then the de-noising process. Figure 3 shows a sample image before and after applying the preprocessing operations. As depicted in this figure, there are several undesired black spots appear in the original image which has been removed after pre-processing step.

Figure 3. A Sample Car Image After Binarization and Noise Removal.

It is worthwhile to mention that for the car plates having a red background, an extra pre-processing is required for the following reasons: in such car plates, the foreground of the plate (digits and words) are written in white color which is different from other plates. So, after binarizing the images in the pre-processing step, the color of the foreground and the background should be swapped to be consistent with the other car plates.

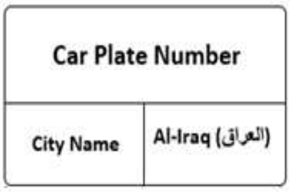
3.3. Car Plate Localization (Detection):

Due to its effect on the total accuracy of the recognition process, car plate detection plays a significant role in any typical ACPR system. Although some of the available ACPR systems perform automatic car plate extraction, accurate localization of plates is still among the hot topics which have attracted researchers' attention. In the current work we have employed, an efficient fast approach, using SURF descriptor (Bay *et al.*, 2006), to detect car plate location.

In the following sub-sections, the structure of the car plates is firstly presented and then the proposed approach for car plate localization will be illustrated.

3.3.1. Car Plate Structure

The car plates of the Kurdistan Region of Iraq, which are different from the rest of the country, have a unique template. As illustrated in Figure 4 the upper part of the plate comprises 1 to 6 digits, written in Arabic script which specifies the plate number. The background colors of the plates are white, red, or yellow. In the right side of the lower part, the unique word of "العراق" (Iraq) appears beside the left sub-part which includes the name of one of the three main provinces of the region: اربيل (Erbil), دهوك (Dohuk) or سليمانيه (Sulaymaniyah).



a)

b)

Figure 4. Car Plate Structure in KRI. A) General Template of Car Plates, B) Sample Car Plates.

3.3.2. Car Plate Extraction

In this work, the Speeded Up Robust Features (SURF) descriptor is utilized for separating the car plate region from the whole image. To do so, a simple and efficient shape matching approach has been used; As mentioned in the previous section, a common sub-image which contains the word "العراق" is available in all car plates of the region. Therefore, according to the structure of the car plates, the SURF descriptor is utilized to find the part of "العراق" (which is available in the right half of the lower part of the plates). The similarity measurement process is performed to match between the target image and a pre-stored binary sample image of word" العراق" (see Figure 5 which, will hereafter be referred to as "base image").

Figure 5. A Sample Image of the Common Part of the Plates (Base Image).

Figure 6 illustrates the matching between a sample input image and the base one. As shown in this figure, despite the variation in the size and orientation of the input image, the key points of the images can be matched correctly, as the SURF descriptor is rotation and scale-invariant.

Figure 6. Matching Between Input and Base Images Using SURF Descriptor.

After locating the car plate in the image, using some geometrical relationship, the full image of the car plate will be extracted and rotated to be aligned properly. The final image of the plate will be fed as an input to the next stage, which is known as the segmentation phase. Figure 7 depicts an extracted car plate from a sample input image.

Figure 7. An Input Image and the Extracted Aligned Car Plate.

3.4. Car Plate Segmentation:

The extracted car plate should be segmented twice to be ready for the recognition phase; the first segmentation separates the upper part of the plate (which includes plate digits) from the lower part (which comprises the city name of the plate and the word "العراق"). On the other hand, the second segmentation should be performed on the upper part to distinguish between the digits.

Since the shapes of the car plates in the region follow a unique standard (in terms of size and location), by dividing the car plate evenly into upper/lower parts and later by dividing the lower part into two equal-size halves, the sub-parts can be easily extracted from the plate.

The final step of segmentation should be performed to extract the digits from the upper part segment of the plate. To this end, the connected component labeling algorithm (He *et al.*, 2017) is applied on the upper part of the plate to extract the individual digits. As the result of this step, separated components that specify available digits will be extracted and finally are saved individually in a separate file for the further process of recognition. Figure 8 depicts the result of the segmentation phase applied on a sample car plate.

(upper segment) (lower part right half) (the lower part left half)

(segmented individual digits)

Figure 8. The Segmented Parts of the Car Plate.

3.5. Car Plate Description and Recognition

The input data of the recognition phase are the extracted digits of the car plates along with the city name of the plate which will be described and recognized, separately.

Similar to any object recognition system, the objects (digits/city name) should be described using a robust descriptor by which the shapes are represented as a set of numerical vectors or an appropriate graph. The underlying descriptors of the digits later will be compared to those which have already been saved in the dataset. The minimum distance between the target image and the saved ones indicates the digit.

In this research, the vertical and horizontal projection of the pixels is utilized as an efficient robust descriptor to recognize each segmented digit/word.

Vertical/Horizontal projection is the procedure that translates two-dimensional images into one-dimensional vector. A horizontal projection vector is the summation of all pixel values (foreground) in each row in the black and white image and is saved in a vector. Similarly, vertical projection is the summation of all pixel values (foreground) in each column in a black and white image and is kept in a vector. Figure 9. shows the vertical and horizontal projection for the sample digit ٦.

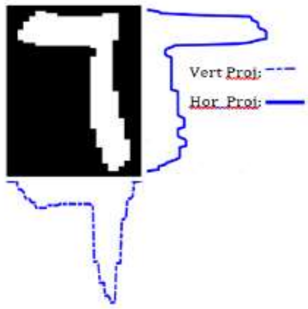


Figure 9. Vertical and Horizontal Projection of Digit "٦".

After extracting both vertical and horizontal projections, the related vectors will be concatenated to generate the hybrid projection vector. Finally, the distance between two hybrid projection vectors X and Y is computed as follows:

$$D(X,Y) = \sum_{i=0}^{n} abs(x_i - y_i) \qquad (1)$$

Where n is the vector size, and abs is a function to compute the absolute value.

The digit (or city name) having the minimum distance from the target image is considered as the recognition result. The recognition process of the digits, in the current work, can be summarized as the following flowchart:

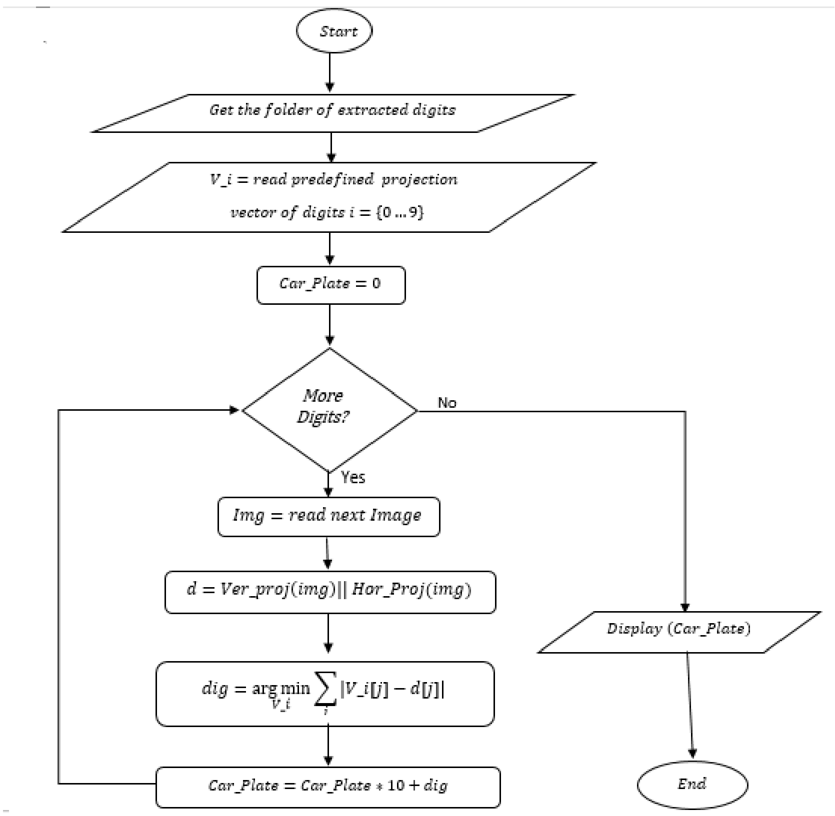


Figure 10. Flowchart Diagram of the Plate Number Recognition.

Almost similar process has been followed for recognizing the city name of the plates in which the horizontal and vertical projections of the city names of the car plates are compared to the reference projections of 3 city names available in the Kurdistan car plates. This will yield the name of the city having most similarity with the projection matrix.

4. Experimental Results

The proposed approach is been implemented in MATLAB and evaluated under various testing scenarios.

4.1. Test Data

There is no standard dataset for the car plates available in the Kurdistan region of Iraq. Therefore, to evaluate the proposed system, the test images have been collected, manually. A digital camera having 12Mega Pixels, dual pixel resolution, f/1.8 aperture and 28mm (wide) have been exploited to take photos of the frontal views of the cars.

The generated dataset includes 200 images which have been categorized into 5 groups, in terms of distance from the camera, view angle, alignment, plate color, and weather condition. The images have been taken in different locations of the region, mainly in Erbil city, and grouped into the following categories (table 1):

Table 1. Categories of the Test Data.

#	Category	No. of Samples	Description
1	Distance of Camera from the Car	45	Images having 1, 2, and 4 meters distance from the camera
2	Car Plate Alignment	60	Car plates have been rotated 0, 45,90 and 180 degree
3	Camera View Points	35	Images are taken from left, right, and frontal views of the car
4	Car Plate Color	30	Car plates having a red, white, or yellow background-color
5	Weather Condition	30	Images have been taken in sunny and heavy rainy weather

Figure 11 depicts some samples of the images used in the current study.

Figure 11. Samples of the Images of the Cars Used for Testing the Proposed System.

4.2. Testing Results

A number of experiments have been conducted on the proposed system to test it under various criteria, precisely. Each category of data is fed to the system separately and the accuracy of the system in terms of both car plate localizing and recognition are computed. Table2. illustrates the percentage accuracy obtained for each testing scenario.

Table 2. The Accuracy of the Proposed System for Different Testing Scenarios.

Scenario / Process	Distance of Camera from the Cars			Car Plate Alignment (Distance=1M)				Camera View points (Distance=1M)			Car Plate Background Color (Distance=1M)			Weather Condition (Distance=1M)	
	1M	2M	4M	0^{o}	45^{o}	90^{o}	180^{o}	Left	Right	Front	White	Yellow	Red	Sunny	Rainy
Car Plate Localizing	**94%**	61%	27%	**94%**	86%	93%	86%	33%	33%	**94%**	**94%**	**94%**	90%	**94%**	60%

Car Plate Recognition	**94%**	61%	27%	**94%**	80%	86%	80%	25%	33%	**94%**	**94%**	**94%**	70%	**94%**	50%

As revealed in table2. different testing scenarios have shown different results. The followings are the summary of the results for each scenario:

- For the first scenario, when the car plate is 1 Meter far from the camera, the highest accuracy will be achieved which is 94%, but for the 4-meter distance, the localizing and recognition is not satisfactory at all (27%). The low accuracy rate for longer distances can be due to the presence of other undesired objects in the image. Therefore, for all the other scenarios, the distance of the camera from the car plate is set to be 1 meter.
- Since the SURF descriptor is rotation-invariant, the obtained result for different alignments of the car plate illustrates the same range of accuracy (between 80% and 94%) which is reasonable.
- When the camera viewpoint is changing, the accuracy of the system will change dramatically, from 94% to 25%. These changes are due to the fact that the SURF descriptor is not affine transform insensitive.
- The proposed system produces the same accuracy for both plates having white and yellow backgrounds. But for the red backgrounds plates, the accuracy is slightly lower as the clinching spot on the plate will be considered as foreground and will decline the accuracy.
- Finally, for the rainy situation, the accuracy rate will deteriorate as the raindrops on the image will affect the distinguishing power of the SURF descriptor.

According to the aforementioned discussions, the proposed system has shown the highest accuracy whenever the car plate image is taken from the frontal view having 1-meter distance in sunny weather. Therefore, the system can be used for the controlled area such as the entrance of the security zones and the parking lots.

5. Conclusion

In this paper, we have proposed an Automatic Car Plate Recognition system that works for the cars in the Kurdistan region of Iraq. The system performs car plate localizing using SURF descriptor and recognition using Horizontal/vertical projection. To evaluate the performance of the system, 200 images under various testing scenarios have been prepared and fed to the system. The results show a high accuracy rate, especially for the controlled environments (94%). During the test, we have noticed that the accuracy of the proposed system is directly proportional to the distance of the camera from the car plate which restricts the applications of the system to the specific domains such as parking lots and security zone entrance. Further improvements on the proposed system, as part of the future works, will let the system be employed everywhere with a higher quality of accuracy. Future works need to be done; firstly, improving the algorithm to be able to detect and recognize car plates in real-time rather than working on taken images. Secondly, enabling the approach to function for car plates of the rest of the cities of Iraq as they are existing in KRI such as car plates of Baghdad, Babil, and Wasit. Lastly, making the algorithm handle all kinds of car plates including different fonts, styles of numbers, and positions of numbers and cities on the plate.

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