IRAQI VEHICLE LICENSE PLATE RECOGNITION USING TEMPLATE MATCHING TECHNIQUE

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ABSTRACT. Recording vehicles movement in Iraq is urgently required to solve many problems of security situation, in addition to other sectors in the domains of statistical, economic, and tourism. In this paper, an algorithm to detect, extract, localize, and recognize the information of the Iraqi vehicles registration plates has been implemented. The extraction algorithm is based on object-features technique and the recognition algorithms are based on template-matching technique. While the plate font is not changed and the camera captures the plate from a fixed angle position, so the templates of the numbers and letters, which were calculated and stored in a specific size matrix, have been processed with the entire images stream of the registration plates. The algorithm has been built and experimented using Matlab package to exploit the GPU capability because the proposed program manipulates huge data and matrices. The collected photos have been taken in fine, cloudy, rainy, and dark (with flash light) conditions weather. The proposal method has shown no effect to distance or image dimensions. The experimental results have shown 96% of accuracy to recognize the numbers. The experiment has also shown a shortcoming in the plate number recognizing which belongs to snapshot from bended position, if the angle of projection bended more than 20° horizontally.

Keywords: Image processing, Pattern recognition, License plate recognition, Intelligent transportation systems

1. Introduction. One of important applications in recent life is the traffic roads information processing. Traffic roads application includes speed breach, toll counting, and vehicles registration plate recognition. Nowadays, the world is directing toward establishing smart cities, where license plate recognition and recording poses an essential subject in the field of intelligent transportation systems.

Because traveling by cars in Iraq is an affordable and most convenient option, this makes tens of thousands of people drive their cars to travel between cities and rare towns. The special case of security situation in Iraq imposes all local governments to install check points on the main entries. These check points always pose bottle necks that cause congestions according to the huge number of cars that come in and go out from the Iraqi cities every day. The policemen in check points usually become exhausted that lead to enable some terrorists, criminals, and dangerous or stolen cars to get through without any action. The cars registration numbers cannot be easily remembered by the human especially when they are dealing with hundreds of wanted cars for long time.
The application of car registration plate recognition is an easy, affordable, and efficient solution for many security and administrative demands. In addition, recording car numbers in a database is useful to get precise statistical data, which could be needed in many applications such as ecology, economy, and transportations. The Iraqi license plate form is subject to the Iraqi federation authority, i.e., its number and letter fonts are identical across the whole country. Therefore, using the template-matching approach is a compatible technique for all regions inside Iraq. The research also shows how the proposal techniques are adequate to achieve the application in the required real-time performance.

Currently, there is much available software capable of recognizing shapes, patterns, and characters from pictures, handwritten text, or objects that are captioned by cameras. Software like OCR and AdaBoost could be used in multi services that include License Plate Recognition (LPR) system.

Some of them are based on histogram information to determine adjustable lower and upper threshold values, which is used to segment the objects from the background. Effect of Floodfill is one method of extracting and recognizing objects based on filling objects algorithm to extract them from the background [1].

Some techniques are based on neural network to position the plate and recognize it. The experimental results of scanning 300 plates have given 95.8% accuracy [2].

Many researchers have conducted their experiments depending on standard Optical Character Recognition (OCR) model algorithm to recognize LP of cars [3].

Regardless of experimenting the algorithm recognition core, many researchers have conducted their experiment of LPR focusing on how to extract the plate image from the row environment, where they are depending on existing standard algorithms for plate number recognition such as OCR model algorithm [4-6]. Mainly, the methods that are used to detect the license plates are based on describing the color, texture, and edges of the plate [7]. However, there are some reliable algorithms to detect objects and extract them from relatively noisy background with high detection rate such as Viola-Jones object detection framework, AdaBoost, Kalman tracker, or Continuous Hidden Markov Model (CHMM) depending on features based recognition methods [8,9].

Other researchers have proposed a long procedure to describe the plate number with aid of radar signal detection. Radar-proposal contains multi stages to process the image including acquisition, de-noising, edge detection, plate localization and calibration, and finally the characters segmentation. After extraction and localization of the plate from the image background, data has been recognized using segmentation. Each character has been described by 13 structural and statistical characteristics [10].

Extraction and recognition of car plates based on color is also proposed and demonstrated, however, it elapsed long execution time than that needed to work in real time, also it is not giving the required accuracy in case of applying this method with different conditions. A proposal of high-speed performance method to detect the car plates based on color saliency and edge features has been introduced by using line filter to decrease the scanned area and picked up the most candidate regions only [11]. To ensure the image detection and recognition processing time run with real-time condition, DSP or FPGA platforms have been dedicated for this purpose [12,13].

In Iraq, LPR has been researched and experimented using different techniques like KNN [14] and OCR [3].

Template-matching technique has also been used with combination of color-features to detect and localize the place of the license plate in car images [15], similarly to [16] but here they reduced the calculation burden using another technique, which is periodic strip search. However, these researches have not subjected their proposals to real-time criterion. Our proposal has shown the elapsed time of recognition is undergoing the condition of real-time with higher accuracy rate. In addition, this research has uniquely
focused on examining the features-based and template-matching techniques to detect, extract, recognize, and interpret the license plate.

This paper has been organized as follows: Section 2 has discussed our proposed theory, Section 3 has shown the experimental approach of our proposal, results of experiment have been declared in Section 4, Section 5 has contained the analysis and discussion, and finally the conclusion has been shown in Section 6.

2. The Proposed Approach. Firstly, the proposed system manipulates a raw image, which is captured by an installed fixed camera. The input image could contain the only License Plate (LP), the LP with front image of the car, or the LP plus the car and a background scene. In all conditions, the LP has to be extracted from the entire image. The algorithm of extraction in this experiment was designed based on the Object Detection with Features (ODF). ODF combines the abilities of selectivity and variability that can be found in template-based and histogram-based detections approaches respectively [17]. Although the detection algorithms basically depend on their classifier and machine learning to process an application in real-time performance, the same detection approach could show a significantly different result if the algorithm has been processed either in a detected GPU or softcore architecture [18]. Generally, the effectiveness of the feature-based detection methods basically increases in case of using a small number of classifiers that will be calculated easier and faster. Furthermore, it is operative to find a set of classifiers that discard the background descriptions and focus more on the promising foreground objects [8]. The proposal detection system has been applied on features recognition. Following equations illustrate the proposed detection algorithms of our system.

1) Suppose the sample image with points \((x_0, y_0), (x_1, y_1), \ldots, (x_m, y_n)\), where every point has been classified according to the value of \((y = 0, \ y = 1)\) to have (negative or positive) representations.

2) All classifiers are weighed, see Equation (1):

\[
1 \leq 2 \left( \frac{1}{2k} \right)
\]

For \(y = 0, 1\) respectively, where \(k, l\) are the number of negative and positive classifiers respectively.

3) All the weights above were normalized, see Equation (2):

\[
\sum_{k=1}^{\infty} w_{1,j} = \sum_{k=1}^{\infty} w_{1,j}
\]

4) For each feature \((k)\), a one-feature constrained classifier \((h_j)\) was trained.

5) The error is determined with respect to \(w_t, e_j\), see Equation (3):

\[
|f_j(x_i) - y_i|
\]

6) The classifier \((f_j)\) with lower error is chosen, and then the weights are updated.

7) Finally, the last classifier will be computed according to the following equation:

\[
f(x) = \begin{cases} 
1 \sum_{i=1}^{m} \beta_i f_i(x) \geq \frac{1}{2} \sum_{i=1}^{m} \beta_i \\
0 \text{ otherwise}
\end{cases}
\]

where \(\beta_i = \frac{1}{\beta_i}, \text{ and } \beta_i = \frac{e_i}{1 - e_i}\)

Secondly, the recognition part of the system was based on template matching. Vehicle registration plate of Iraq contains two numeral symbols (Hindi and Arabic), which refer to the same license number, in addition to other registration information. The experiment has been applied onto Hindi numeral symbols, Arabic letter, type of vehicle, and the
governorate name. This information specifies the required registration data of official authorities. Actually, recognizing the registration number of the vehicle plate is representing the most complex technique comparing to other plate data because it must be calculated according to its digit order. The proposed research has dealt with Hindi numeral rather than the Arabic numeral symbols for two reasons. Firstly, they are appearing bigger, so they can be distinguished faster and better. Secondly, the Hindi numbers shapes are more morphologically differentiated against each other and against the Arabic alphabetic letters, too.

Hindi numeral symbols are in the following shapes (० १ २ ३ ४ ५ ६ ७ ८ ९). As we mentioned, the numbers potentially have some unique features different from each other leading to be recognized using cross-correlation algorithm. However, there are some symmetry between number two (२) and number three (३). In addition, there is some symmetry between number one (१) and the Arabic letter alpha (ا). Moreover, the zero symbol (०) comes in small solid diamond shape, which could match with some other punctuation or symbols. Nevertheless, the experiment never encountered any fuzzy results because the matching degree between all symbols in above argument never reached more than 0.72 while the algorithm condition has been set to 0.8 or more to indicate the identifications between objects.

3. Implementation of the Algorithm. The proposed system processes the entire image through a sequence of steps. However, these steps are categorized into two stages. The first one is the image detection and extraction, and the second one is the recognition and interpretation. Figures 1(a) and 1(b) illustrate these stages respectively.

![Block diagram of the whole proposed system](image)

**Figure 1.** Block diagram of the whole proposed system

3.1. License plate detection and extraction. Our experiment is based on ODF to extract the LP from the camera photo. The extraction procedure of the system has been explained in the following.

3.1.1. Image preprocessing. To ensure faster manipulating performance and higher accurate results, the input image is preprocessed in a way to reduce the data of the matrices calculation. Reducing the input matrices operands into smaller binary string enables the GPU to manipulate more amounts of numbers at the same time. For example, if the GPU data width size of the system is 64-bits, this means it is able to implement an operation consisting of 16 (8-bit operands) simultaneously [19].
3.1.2. **Picking up the common features of ILP.** To extract the Iraqi License Plate (ILP) from the entire image, the algorithm firstly finds the prominent features such as corners, line-intersection, roundish lines, some dominant letters, and other shapes details using ODF algorithm core. A blank license plate was created by removing all specifications and remaining a frame with the common shapes only. Figure 2 shows how the algorithm selects hundreds of object features of the plate.

![Blank license plate with all ODFs that are specified by the proposed extraction algorithm](image)

**Figure 2.** Blank license plate with all ODFs that are specified by the proposed extraction algorithm

The green circles around the points refer to the selected features. All these features were stored in \((M \times 2)\) array that is containing information about points coordinates of SURF features detected in 2-D grayscale image.

The detection and extraction algorithms firstly surf the features of blank LP to be stored in a vector. Then the ODF of overall scene is detected. A comparison between the ODF of the blank plate and the whole scene has been deducted later. Only the matched features between the car image and the LP image have been determined. Finally, to specify the LP location, we define geometric transformation objects. Figures 3(a)-3(f) illustrate all the above detection and extraction steps.

![Extraction approach window of the proposed system](image)

**Figure 3.** Extraction approach window of the proposed system
3.2. **Recognition stage.** The localized LP sub-image in Figure 3(f) was cropped from the entire image to be processed in the next stage (the recognition). Figure 4 shows a flowchart of the overall recognition procedure.

![Flowchart of the recognition algorithm](image)

**Figure 4.** Flowchart of the recognition algorithm

3.2.1. *LP image pre-processing.* The extracted LP image is transferred to a gray-scale in order to suppress the unbalanced brightness and reflection. Also, gray-scale image processing is faster and gives more appropriate outcome to the next stage.

3.2.2. *Binarizing and resizing the LP image.* The image matrix was resized to 400 × 800 pixels before binarizing it into a BMP format. Formatting the image matrix in BMP is to reserve the data arrangement undistorted unlike other compact formats, like JPG and PNG, which are distorted if they are compressed and decompressed again. Casting the image with 400 × 800 dimensions is because the templates have been taken from the LP image of the same dimensions. Resizing the LP image has proven the system stability to variant input image resolutions as shown in Table 1. The numbers and the state name templates have been chosen in (150 × 70) and (80 × 200) dimensions respectively. The size of the template and the LP image were necessary to calculate the digit order of the number and appropriately interpret its position in order to receive and store the correct
### Table 1. Image resolution variant results

<table>
<thead>
<tr>
<th>Entire image resolution</th>
<th>Accuracy rate</th>
<th>Processing time</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 × 200</td>
<td>96%</td>
<td>1.2 sec</td>
</tr>
<tr>
<td>200 × 400</td>
<td>96%</td>
<td>1.32 sec</td>
</tr>
<tr>
<td>1419 × 2884</td>
<td>96%</td>
<td>1.53 sec</td>
</tr>
<tr>
<td>1546 × 3082</td>
<td>96%</td>
<td>1.7 sec</td>
</tr>
</tbody>
</table>

#### 3.2.3. Template matching

Cross-Correlation (CC) has been used in LP recognition. In most of image matching applications, CC is usually preceded by normalization operation firstly to eliminate the unbalanced lighting and exposure conditions, which could vary the brightness of the image against the templates. In our proposal, image normalization is not required because the image has already been restricted in binary form (0 and 1 only). So the research proposal has removed the normalization step.

The cross-correlation of a template, \( T(x, y) \) with an image \( I(x, y) \) is represented in this equation:

\[
\frac{1}{m} \sum_{x,y} \frac{1}{\sigma_I \sigma_T} (I(x, y) - \bar{I}) (T(x, y) - \bar{T})
\]

where \( m \) is the number of pixels in the template \( T(x, y) \) and the image \( I(x, y) \). \( \bar{I} \) is the average of \( I \) and \( \sigma_I \) is standard deviation of \( I \).

The peak of cross correlation in case of ideal matching reaches 1, but the matching criterion of our experiment has been laid in range of (0.8-1.0). After interpreting the plate data, the system stores the data in a document file for recording purpose. Matlab GUI window of the LP recognition system steps is illustrated in Figure 5.

**Figure 5.** GUI of the system recognition

number. Moreover, fitting templates with this size is to prevent any intersection between them on the LP image.
4. **Results.** The experiment was applied onto 50 license plates. The accurate readings were 48 (96% accuracy). While the captured image resolution does not influence the accuracy reading in this proposed system, however, resizing the plate image to smaller size will increase the speed of performance. Table 1 shows different entire image resolutions with their accuracy rate experimented under various weather conditions. As shown in Table 1 the diversity of entire image resolution does not affect the accuracy rate.

5. **Analysis and Discussion.** The high-level of accuracy and the real-time processing are urgent attributes in case of dealing with car registration plate recognition and recording. Especially in case of dealing with a massive number of vehicles, the high percentage of error could show a real damage in working flow of this application.

The system never encountered any confusing with some semi-identical shapes. For instance, the shape of number one in Hindi form (.subplots) is semi-close to the shape of alpha letter in Arabic (.subplots). Likewise, number two and number three, (.subplots) and (.subplots) respectively, have never recognized interchangeably. In addition, the number zero (.subplots) has not matched inappropriately to any undesired dot or spot on the LP image. This is because the matching degree of similarity between these shapes has never exceeded 0.72, while the threshold similarity has been set to 0.8 in our proposal algorithm. Our recognition approach also has proven it is not affected by the other logos, fixing nails, and hologram labels.

The proposed program did not correctly recognize an image with dark shadow spots. This belongs to binarization stage which has depended on global threshold rather than local threshold, where local threshold is more effective in heterogeneous illumination. Likewise, the experiment has shown the system inability to recognize the LP image if the horizontal axis is tilted more than $20^\circ$.

The accuracy rate could be decreased in case of using different camera to take the samples of numbers than the installed camera on the roads.

6. **Conclusion.** Using template-matching method gives accurate and quick outcomes. The proposal system proved its efficiency on the main entries of the Iraqi cities in spite of huge numbers of cars. The Matlab Computer Vision toolbox was used to exploit the GPU ability, which increased the processing performance significantly.

As future work, enhancing the system performance can be researched in direction of parallel processing, dedicated hardware, or system on reconfigurable chip (FPGA boards). Also, more accurate results can be obtained if machine or deep learning has been experimented to report the unreadable LP at the beginning iterations. The Arabic numeral symbols could also be recognized in parallel with Hindi numbers for verification purpose.

**REFERENCES**


