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Design of Automatic Number Plate Recognition System for Yemeni Vehicles with Support Vector Machine

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Abstract: Automatic Number Plate Recognition (ANPR) is an important tool in the Intelligent Transport System (ITS). Plate features can be used to provide the identification of any vehicle as they help ensure effective law enforcement and security. However, this is a challenging problem, because of the diversity of plate formats, different scales, rotations and non-uniform illumination and other conditions during image acquisition. This work aims to design and implement an ANPR system specified for Yemeni vehicle plates. The proposed system involves several steps to detect, segment, and recognize Yemeni vehicle plate numbers. First, a dataset of images is manually collected. Then, the collected images undergo preprocessing, followed by plate extraction, digit segmentation, and feature extraction. Finally, the plate numbers are identified using Support Vector Machine (SVM). When designing the proposed system, all possible conditions that could affect the efficiency of the system were considered. The experimental results showed that the proposed system achieved 96.98% and 99.19% of the training and testing success rates respectively.

Index Terms: ANPR, Image Segmentation, Digit Recognition, SVM.

1. Introduction

Various recognition systems have been developed to be used in several security and traffic applications, such as airport parking, maintaining law enforcement on public roads, access and border control, or tracking of stolen cars. Automatic Number Plate Recognition (ANPR) systems have become an effective and promising research topic computer vision. ANPR is a technique applied to observe and recognize vehicle number plate characters from static and/or moving vehicle images [1,2,3,4,5,6]. Many machine-learning approaches such as Deep Learning (DL), Support Vector Machine (SVM), and Neural Network (NN) methods, are used to recognize and detect vehicle plate licenses [7].

Vehicles traveling on public roadways in Yemen and many other countries are required by law to carry a clearly visible placard with a unique identifier registered with the local government. This placard, most commonly called a license plate (LP), can contain various symbols, letters, numbers, logos, etc. based on local government regulations and the class of the vehicle. According to the annual report of the Traffic Police Department [8], the registration of vehicles' number in Yemen over the past eight years is shown in Fig.1.

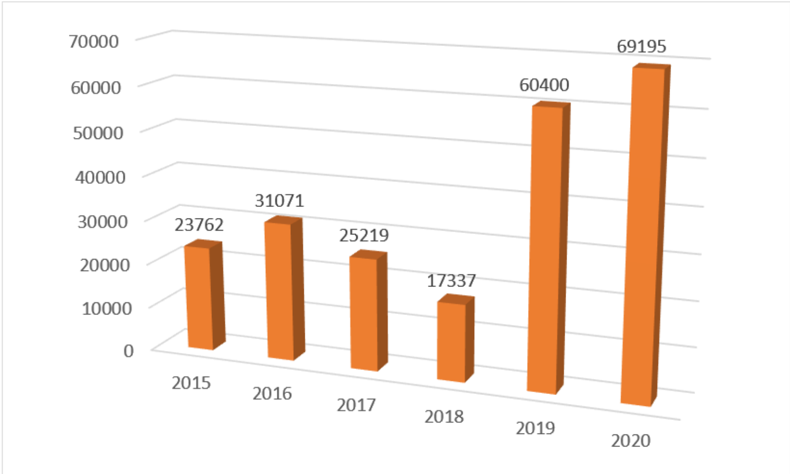
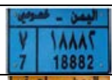
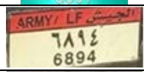


Fig.1. Registration of vehicles' number in Yemen in the past six years

Yemeni LP can be classified into two main categories: Regular LP and Special LP as shown in Table 1.

Table 1. Examples of Yemeni car plates

Category	Vehicle Type	Plate Background Color	Foreground (Character) Color	Plate Format
Regular	Privet	Blue	Black	
	Taxi	Yellow	Black	
	Transport	Red	Black	
Special	Governmental	Green	White	
	Military	White and Red (new form)	Black	
	Police	Blue	White	
	Temporary (not stable)	Blue Pink	White White	 
	Diplomatic Mission	Red and white	Black	

In this work, the regular class of LP is considered. The layout of Yemeni LP is depicted in Fig.2.

Fig.2. Layout of Yemeni car plate

Region 1 consists of two words (fixed word "اليمن" and variable word according to the type of the vehicle. In this work, we consider only three types: private transport, public transport and Taxis, as shown in Fig.3. Region 2 consists of the Governorate Number to which the car belongs. Region 3 contains the number of cars (Indian numbers in the first row and Arabic numbers in the second row). The Arabic words and their corresponding English words are listed in Table 2.

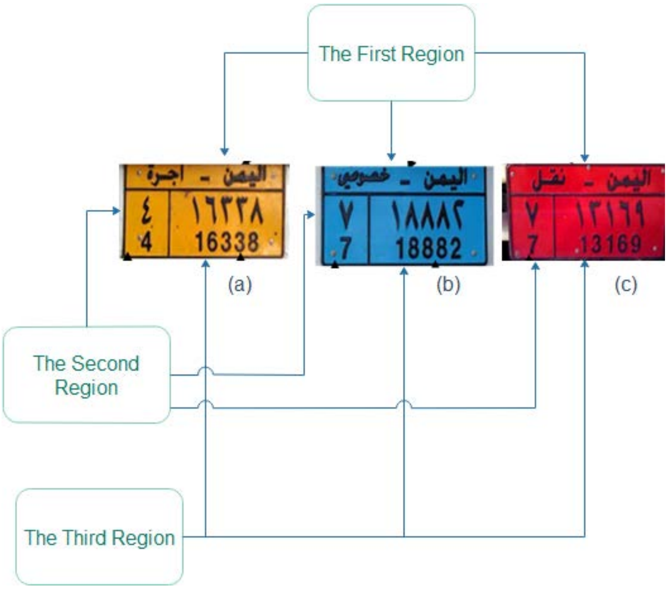


Fig.3. Examples of yemeni car plates: (a) public, (b) private, (c) carrying

Table 2. Arabic Words and their corresponding words in English

In Arabic	Pronounce in English	In English
اليمن	Alyaman	Yemen
خصوصي	Khososi	Private
اجرة	Ojira	Taxi
نقل	Naql	Transport

In this work, an ANPR system is designed to recognize Yemeni vehicle number plates using SVM. In the proposed system, vehicle images were first collected from public places in Ibb City, Yemen. Second, the region of interest identification of the LP is extracted with relevant features from the vehicle plate. Third, the Arabic digit part is extracted from the plate and then each numeric character is segmented. Finally, SVM is used to recognize and compare the character outputs (digits) from the previous step. For seeking the comparison, SVM is compared with Template Matching and Distance Measure.

The rest of this paper is organized as follows. Section 2 presents the related works. Section 3 presents system implementation methodology. Section 4 discusses simulation and results, and Section 5 concludes the paper.

2. Related Works

Several methods have been used for ANPR, including machine learning and deep learning [7]. The authors in [9] reviewed various techniques for the vehicle number-plate detection and recognition. The review covered the main issues including: which methods have been used or developed, what datasets have been used and what kinds of characters have been recognized. The authors in [10] reviewed the approaches and techniques used in automatic license plate recognition in literature. The future research directions are presented to optimize the developed solutions to work under critical conditions.

On the other hand, some systems were proposed in various countries for number plate recognition of vehicles. In [11], an optimized algorithm was developed for Persian License Plate Recognition using neural network and the accuracy percentage was 92.85%. In [12], a license plate recognition method has been proposed to detect and recognize license plates in single-frame images using SVM. Two steps were used: License plate detection and character recognition. The proposed system was applied to Spanish and Indian license plate. In [13], a model for a license plate recognition for Libyan vehicles was proposed. The proposed model consists of three stages including: plate detection, character segmentation and OCR by using SVMs. The achieved accuracy was 83.3% in 5 seconds. A robust vehicle detection system was proposed in [14] to detect the front vehicles. SVM and Decision Tree (DT) classifiers were used for the classification. The accuracy obtained was 93.75%. An Artificial Neural Fuzzy Inference System has been used to propose a practical plate number recognition system in [15]. The proposed model was evaluated using the FZU Cars dataset [16] and the HumAIn2019 dataset [17]. The accuracy obtained was 97.84 %. In [18], an automated system was proposed to recognize vehicle license plates at the campus entrance of the National Energy University in Malaysia

(UNITEN) using image processing-based techniques. The detection accuracy, a successful plate number segmentation rate and the accuracy of plate recognition were 91.58%, 91% and 80% respectively. A new automated license plate detection system has been proposed in [19] to detect vehicles in Japan. An SVM based on negative and positive examples was used in the proposed system. The achieved detection rate was approximately 90%. The authors in [20] proposed an automatic system to detect and recognize vehicles license plates of Saudi Arabia using DL techniques. In the proposed system, Faster Region-based Convolutional Neural Networks (Faster-RCNN) were used to detect LP and CNN was applied to recognize the characters from LP. The accuracy rate of detection and recognition were 92% and 98% respectively. In [21], LP recognition system was proposed and applied on Tunisian LPs. The developed system was carried out by three steps: LP identification using RCNN, LP segmentation Caltech and Application-Oriented LP. The obtained accuracy was 97.5%.

3. System Implementation Methodology

The proposed ANPR system has two main stages which are the training stage and recognition stage. The general training model consists of three general stages: dataset collection and pre-processing, splitting, and training and testing as shown in Fig.4.

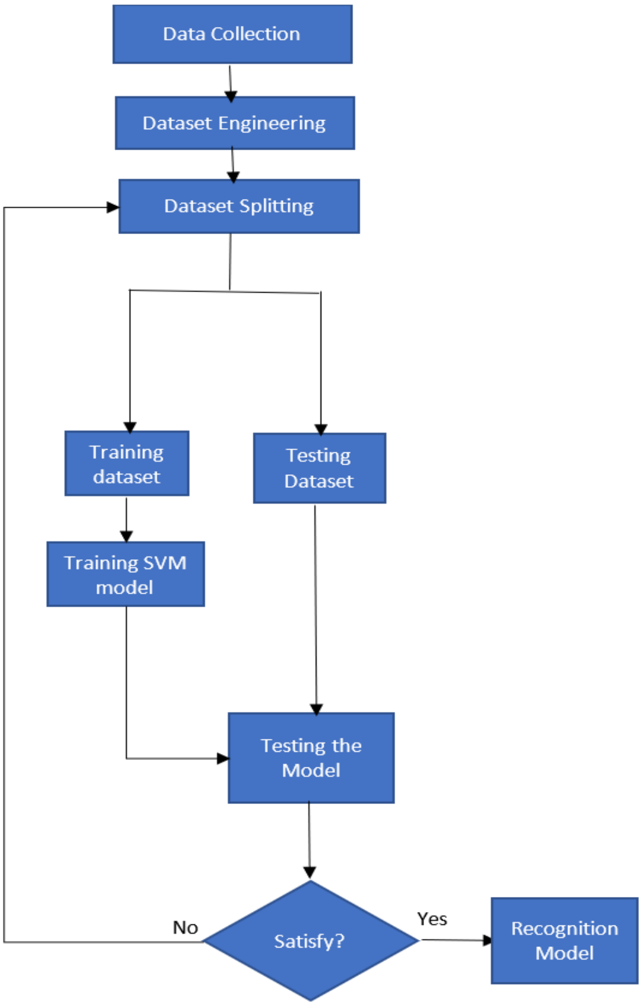


Fig.4. General training model

3.1. Dataset Collection and Pre-processing

Generally, a common problem affecting the current research community is the difficulty in the obtaining dataset due to the time and cost of the collection. Therefore, one contribution of this work is the dataset collection which consists of 1492 digit extracted from 438 images that have been collected manually from different places at Ibb city, Yemen using cameras with the resolutions of 8 and 13 Mpixels. Each sample is a 24 feature vectors which has been extracted as shown in Fig.5. These samples are divided into 995 training set and 497 testing set.

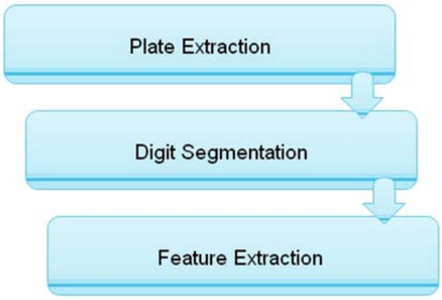


Fig.5. Block diagram for the dataset collection

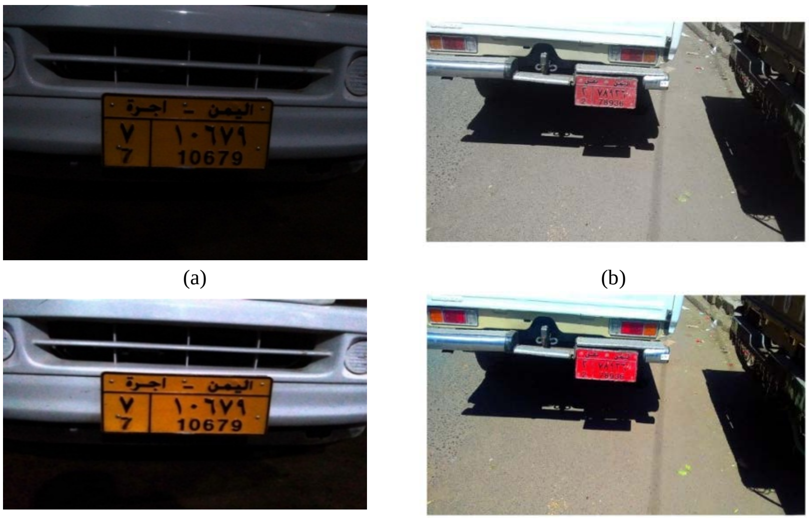
A. Plate Extraction

This stage should be performed carefully to extract LP with relevant features from the acquired images, as shown in Fig.6. Some preprocessing should be applied before plate extraction. The images are normalized to a standard dimension (i.e., NaN x 480), NaN referred to Not A Number in the MATLAB software, and it is used to maintain the aspect ratio of the image when used with *imresize*( ) function. Then, the color system of the images is converted form Red Green Blue (RGB) to Hue Saturation Intensity (HSI). After that, the color contrast is enhanced using Adaptive Histogram Equalization (AHE) [22] to facilitate the color filtering task, as seen Fig.7.

The color filtering is done by removing undesirable colors from the collected images, as shown in Fig.8. To perform the color filtering process, the ranges of hue and saturation bands are selected carefully by observing many images, as shown Table 3.

(a) Input Image (b) Output Image

Fig.6. Localization of the number plate region



(a) (b)

(c) (d)

Fig.7. (a) and (b) Before the color enhancement, (c) and (d) After the color enhancement

As shown in Fig.8, the filtered image may contain some regions that are similar to the plate’s color. It may also contain black holes. These undesired regions should be removed from the filtered image because they will affect extraction process. The process of removing these undesired regions from the filtered image is implemented through the following steps:

First, the color image is converted into gray using:

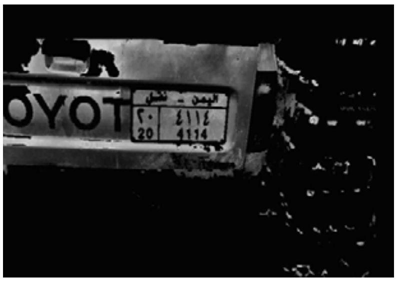
$$I_g(i,j) = 0.299 \times R + 0.587 \times G + 0.114 \times B \tag{1}$$

where R, G and B are the red, green and blue components of a pixel at position (***i, j***) in the RGB image, see Fig.9a.

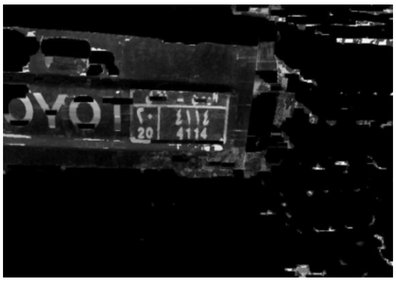
In the second step, the image contrast is improved by using, AHE which manipulates uneven illumination in the real environment, see Fig.9b. In the third, Bottom-Hat Transformation [23] is used to enhance the focus on the number plate area and the black regions, see Fig.9c. In the Fourth step, the resulting image is converted into a binary image using a specific threshold chosen by Weller's Algorithm [24,25,26]. After binarization, any small unwanted regions found are removed, as shown in Fig.10a. In the Fifth step, the closing operation is applied to the result image from the previous step to connect the remaining regions.

Fig.8. Samples of images after color filtering operation

(a)



(b)



(c)

Fig.9. (a) Gray-scale image, (b) Enhanced image, (c) Result of Bottomhat transformation

Table 3. Range of values for each band specified for each Yemeni plate colors

Color	Band Range	
	Hue	saturation
Blue	0.50 – 0.61	0.30 – 1.00
Red	0.95 – 1.00	0.70 – 1.00
Yellow	0.00 – 0.16	0.60 – 1.00
Green	0.47 – 0.50	0.70 – 0.90

(a) (b)

Fig.10. (a) Result of binarization & remove small regions, (b) Result of closing & dilation

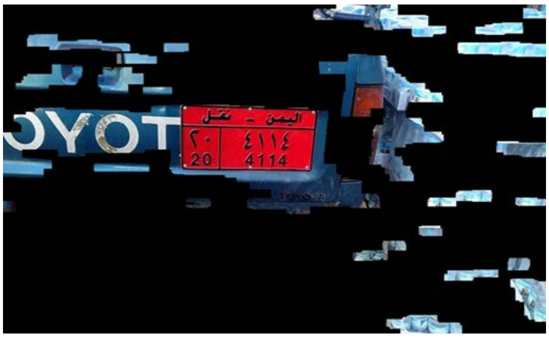


Fig.11. Taking the regions from the original enhanced RGB image

(a) (b)

(c)

Fig.12. (a) Result after repetition, (b) largest region selection, (c) The extracted plate

Then the small holes are filled using the dilation process as shown in Fig.10b. In the Sixth step, the result image from the previous steps is used as a mask to extract the objective regions from the original enhanced RGB image, as seen Fig.11.

In the seventh step, the previous steps are repeated on the resulting image from the sixth step with some changes in the values of structuring element sizes and threshold to locate and extract the number plate perfectly, as shown in Fig.12.

B. *Digit Segmentation*

After extracting the plate, the Arabic digit portion is then isolated and each numeric character is segmented. The flowchart diagram of the digit segmentation module is shown in Fig.13. Depending on the orientation of the extracted plate, orientation adjustment may be necessary, as illustrated in Figs. 14 and 15. Additionally, size normalization may be required to eliminate variations in character size.

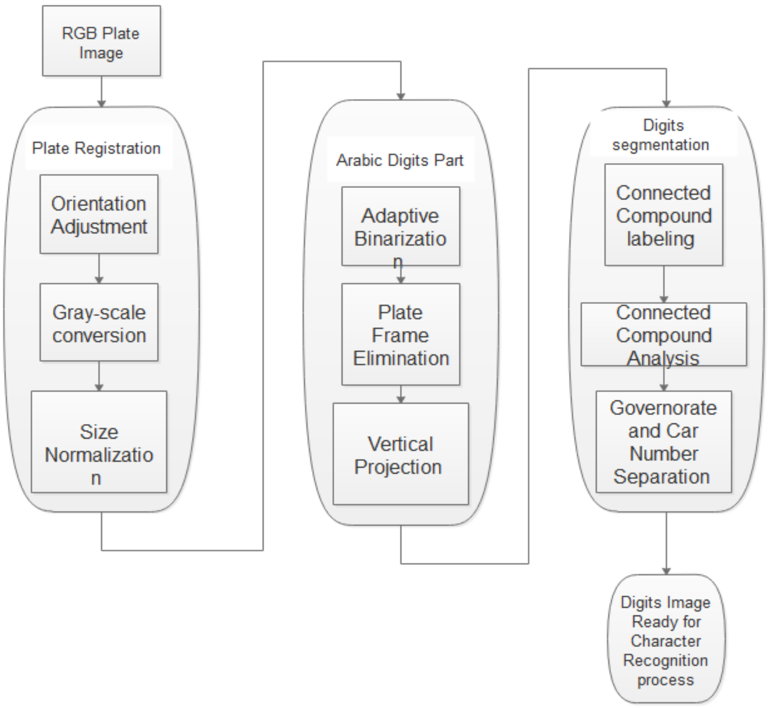


Fig.13. Flowchart diagram of plate segmentation stage

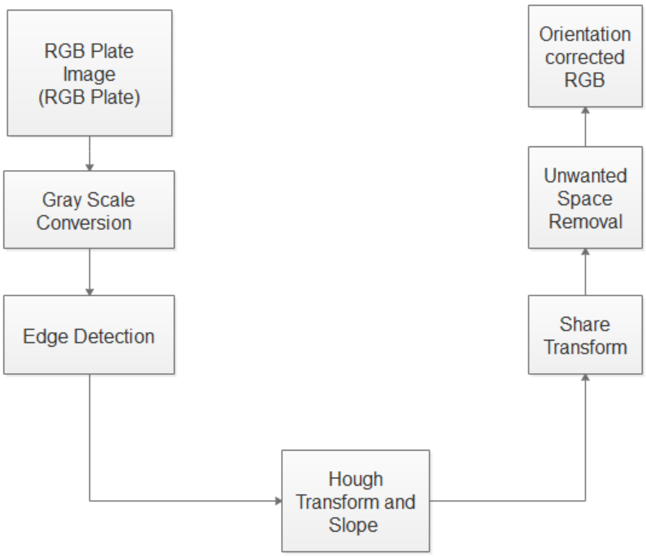


Fig.14. The procedure of orientation adjustment

a. Arabic Digits Part Extraction

This operation aims to extract the lowest part of the plate (i.e., Arabic Part) through three steps.

1. **Adaptive Binarization:** Because of dealing with real environment, the lighting condition is not uniform. As a result, the adaptive binarization is used instead of the global binarization, the output image is shown in Fig.16b.
2. **Plate's Frame Elimination:** Removing the frame of the plate in order to facilitate the segmentation process, the output image is shown in Fig.16c.
3. **Vertical Projection Analysis:** The vertical projection of the image is a graph which represents an overall magnitude of the image according to ***y*** axis. After computing the vertical projection, a dynamic threshold is computed to slice the resultant image into many parts and then selecting the correct region (the lowest region). The output image is shown in Fig.16d through Fig.16g.

Fig.15. Result of orientation adjustment

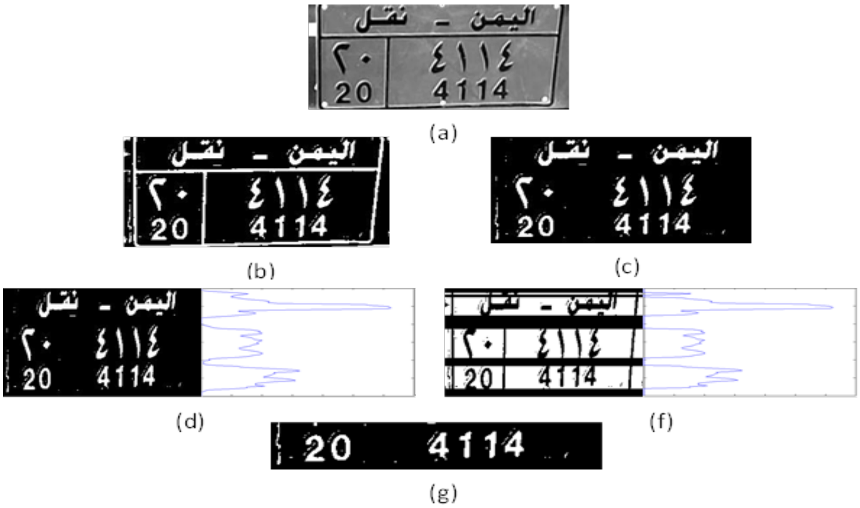


Fig.16. (a) Gray-scale plate image, (b) Binarization, (c) Frame elimination, (d) Vertical projection, (f) Sliced plate by dynamic threshold, (g) Extracted Arabic part

b. Arabic Digit Segmentation

In this stage, each Arabic digit will be segmented through the following steps:

1. Labeling each connected component in the Arabic digit part.
2. Removing the undesirable regions and analyzing the connected components by using area property, aspect ratio and height property, see Fig.17.

(a) (b) (c)

Fig.17. (a) Connected components, (b) Area and aspect ratio filtering, (c) Height filtering

C. Feature Extraction

The most important process in the character recognition system is the feature extraction step. A lot of feature extractions methods have been proposed for recognition purpose [27] such as statistical features, global transformation and structural features. In this work, the zoning feature is used which is one of the statistical features. Zoning based feature extraction is one of the most popular methods in which the character image is divided into predefined number of zones and a feature is computed from each of these zones [28]. In the proposed system, each digit is divided into 4×6 (24 zones) as shown in Fig.18. One feature will be used which is called box feature in the proposed system as shown in Fig.18.

In the box feature approach, for each pixel (i, j) in the kth box, phase angle and Euclidian distance of all black pixels are computed by considering the upper left corner of each box (zone) as the absolute origin by using the equations (2) and (3) respectively.

$$\theta_k = \tan^{-1}\frac{-j}{i} \tag{2}$$

$$d_k = (i^2 + j^2)^{1/2} \tag{3}$$

Finally, the average of the two features is computed for each box as follow:

$$\gamma_b = \frac{1}{n_b}\sum_{k=1}^{n_b} d_k^b \tag{4}$$

$$\alpha_b = \frac{1}{n_b} \sum_{k=1}^{n_b} \theta_k^b \tag{5}$$

Where n_b is the number of pixels in the bth box.

3.2. Model Training

There are many popular techniques that can be used for digit recognition. In the proposed system, SVM is used. It is a supervised learning classifier which finds the optimal hyperplane (optimal solution) with maximal margin to separate between different data points in a given space. Due to its advantages, it is widely used in many applications such as image classification and recognition [29].

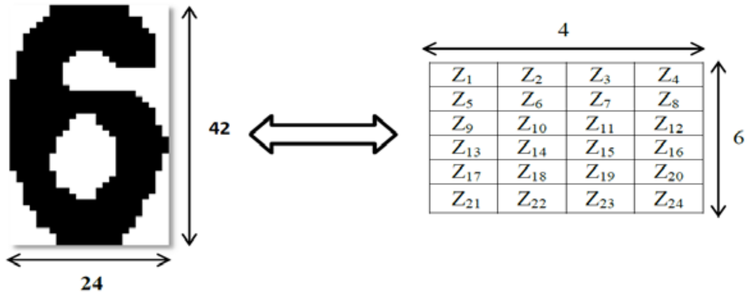


Fig.18. Division of the digit image to 24 zones, each of 7×6 (42 pixels)

In the proposed system, LIBSVM library is used which is the most popular SVM dedicated library endorsed by both researchers and ordinary users [30]. The LIBSVM library consists of two basic functions. The first function is *svmtrain* which is used for the training process and gives a trained model used to recognize the unknown digits. The second function is *svmpredit* which is used for the recognition process based on the model resulted from the training function.

A. Setting the Important Parameters for LIBSVM Library

The main parameters of SVM are regularization constant (***C***), stopping criterion and kernel parameters ($\boldsymbol{\sigma}$).

a. Soft Margin (Regularization) Parameter (C)

Selection of the suitable value of *C* can balance the trade-off between margin maximization and error minimization [31]. After examining many values of *C* experimental, it is found that when ***C***=10, it yields excellent classification success rates for both training and testing datasets.

b. Kernel Parameter

There are four popular kernel functions including: linear, polynomial, Radial Basic Function (RBF) and sigmoid. Due our experiments, RBF kernel function is used in the proposed system.

RBF is used as a kernel function for nonlinear classification with equation (6): [32]

$$K(x_i, x_j) = exp\left(\frac{\|x_i - x_j\|}{2\sigma^2}\right) \tag{6}$$

Where $\boldsymbol{\sigma}$ is the kernel parameters which affects the transformation of data and hence it can control the shape of the separating hyperplane, here $\boldsymbol{\sigma}$ is assumed to be 0.0023.

B. The Basic Steps for Training and Recognition

The Basic Steps for Recognition using SVM are as follows:

1. The Extracted features are put in a matrix *F* in which the rows represent the features and the columns represent feature values.
2. Construct a second matrix *T* that specifies the target for each row in matrix *F*.
3. The dataset is divided into 995 samples for training and 497 samples for testing.
4. The model is trained using *svmtrain* function using the dataset and taking into account setting the parameters as *C*=10 and σ=0.0023 with choosing the RBF kernel function as follow: *model = svmtrain(T,F, '-c 10 -g 0.0023');*
5. Extract the features from the coming unknown digit.
6. Use the *svmpredict* function to recognize the unknown digit.

3.3. Other Recognition Approaches

For seeking the comparison, two other recognition approaches are used which are Template Matching and Distance Measure Approach.

A. Template Matching

One of the methods used for character recognition is template matching [33,34]. When applying this approach, the clipped digit is first normalized to the size of the number template images (i.e., 42x24). Next, the correlation value is computed between each number source image and the number template images using the following equation:

$$s(I,Tn) = \frac{\sum_{i=0}^{w}\sum_{j=0}^{h}(I(i,j)-|I|)(Tn(i,j)-|Tn|)}{\sqrt{\sum_{i=0}^{w}\sum_{j=0}^{h}(I(i,j)-|I|)^2}\sqrt{\sum_{i=0}^{w}\sum_{j=0}^{h}(Tn(i,j)-|Tn|)^2}} \quad (7)$$

where $I(x, y)$ is the input character, $Tn(x, y)$ is the template n. Finally, the template with highest value is chosen as a number representative for the source image. The main problem associated with this method is that a small noise will affect the recognition process.

B. Distance Measure Approach

It is used to identify inter-character distance. This approach is described briefly in the block diagram shown in Fig.19.

The similarity distance can be given by:

$$D(T_i,U) = \sum_{j=1}^{N}\frac{abs\left(T_i(j)-U(j)\right)}{\sigma_i(j)} \quad (8)$$

Where $T_i(j)$ is the j^{th} feature mean value of i^{th} template, (j) is the j^{th} feature extracted from the unknown digits, N is the number of features, and $\sigma_i(j)$ is the j^{th} feature standard deviation value of i^{th} template.

4. Experimental Results and Discussion

The results were obtained using MATLAB R2020. The proposed system was tested on 438 car images captured by cameras with resolutions of 8 and 13 megapixels. These images were taken under various illumination conditions, distances, and angles, ranging from easy angles (0 degrees) to difficult angles of up to 45 degrees.

4.1. Detection Stage

The proposed system is tested. The success rate of plate extraction, Arabic part extraction and digit segmentation stages are shown in Table 4. The success rate represents the ratio of the successful images to all images tested. It is observed that the success rates of plate extraction, Arabic part extraction, and digit segmentation are 95.66%, 98.81% and 96.62% respectively.

4.2. Training Stage

Table 4 shows the distribution of the used digit images which are used for training and testing. There are 1492 binary images with a fixed size of 42×24 pixels, as seen in Table 5. The training set is 995 digit-images and 497 digit-images for testing. The training and testing accuracy for SVM are shown in Table 6. The results presented in Table 6 indicate the accuracy of SVM during training and testing, while utilizing the box feature extraction method with 9 and 24 zones. The analysis demonstrates that with σ =0.03, 9 zones and C=10, the success rate was 98.93%. Conversely, with σ =0.0023, 24 zones and C=10, the success rate was found to be 99.73%. For seeking the comparison, the success rate template matching approach and distance measure approach are shown in Table 7.

Table 4. Success Rate of Plate Extraction, Arabic Part Extraction and Digit segmentation stages

Stage	No. of Images	No. of successful images	Success Rate
Plate Extraction	438	419	**95.66%**
Arabic Part Extraction	419	414	**98.81%**
Digit segmentation	414	400	**96.62%**

Table 5. Test materials of the recognition classified into10 classes

Class Number	Number of samples	The Sample
0	85	0
1	246	1
2	178	2
3	146	3
4	159	4
5	121	5
6	114	6
7	234	7
8	104	8
9	105	9
Total	1492	

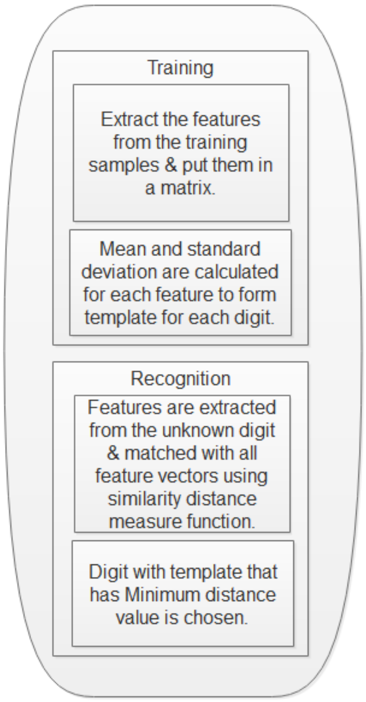


Fig.19. Distance Measure Approach

Table 6. Success rate for SVM on training and testing data sets using box feature extraction method with 9 and 24 zones

Method	**No. of Digits**	**Training**	**Testing**	**Training Success**	**Testing Success**	**Training accuracy**	**Testing accuracy**	**Success Rate**
9 zones, σ =0.03 and C=10	1492	995	497	994	482	**99.89%**	**96.98%**	**98.93%**
24 zones, σ =0.0023 and C=10	1492	995	497	995	493	**100%**	**99.19%**	**99.73%**

Table 7. The success rate of Distance Measure And Template Matching approaches

Method	**No. of Digits**	**Success**	**Success Rate**
Distance Measure 9 zones	1492	1475	**97.65%**
Distance Measure 24 zones	1492	1477	**98.99%**
Template Matching	1492	1438	96.28%

It is observed that when SVM with 24 zones, σ =0.0023 and C=10, the proposed system achieved the best success rate. Fig.20 illustrates the graphical user interface working environment of the proposed system with sample image.

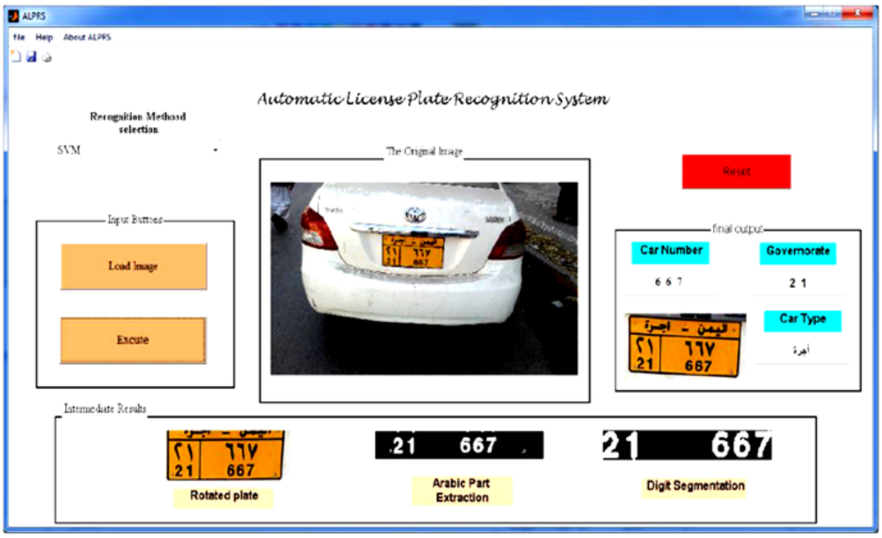


Fig.20. Graphical user interface working environment of the proposed system

4.3. Comparison with Previous Works

Table 8 displays a comparison between the proposed system and other referenced systems, with a primary focus on accuracy.

Table 8. Comparison of the proposed system and other published works

Reference No.	Recognition method	Quantity	Accuracy %	Recognition Character
[11]	Using Neural Network and Image Filtering	N/A	92.85%	Persian
[35]	Connected component analysis, integrated edge-based technique	2800	94.4%	English
[36]	Neutrosophic set based Genetic algorithm, K-means clustering, CCLA, edge detection	250	96.67% for Egyptian and 94.27% for English	Arabic and English
[37]	ORC, Template Matching	900	93%	Urdu
[38]	SSD based approach	28320 class A, 30956 class B	99.1%	Chinese
[39]	Compressive Sensing Technique, SVM	1010	98.8%	English
[40]	Gradient based Segmentation, Edge detection techniques	78	94.87%	English
[41]	Image processing techniques, OCR	N/A	82.6%	English
[42]	Image Processing Techniques	250	85%	English
[43]	Morphological transformation, gaussian smoothing, Gaussian thresholding, and KNN	101 images, 768 characters	Detection: 98.02% and recognition: 96.22%	English
[44]	Feature extraction model and BPNN	100	97.7%	Chinese
[45]	OCR –Template Matching	110	89.7%	English
[46]	Bounding box feature and template matching OCR	14	92.85%	English
The proposed work	SVM, 24 zones	438 images, 1492 characters	99.19%	Arabic

5. Conclusions

In this paper, an ANPR system was developed to extract and recognize the number of Yemeni license plate. The proposed system consists of two main stages which are the training stage and recognition stage. The training model consists of three general stages including dataset collection and pre-processing, splitting, and training and testing. The dataset size was 438 images and collected manually from different public places at Ibb city, Yemen. During the design and the implementation of the system, all the possible conditions that may affect the efficiency of the system were taken into account such as camera's angle variation, distance variation between the camera and the vehicle and complicated conditions, such as fogy, rain, dirt, low/high contrast, shadow, night, and distorted and rotated LPs. SVM was used due to its advantages in the recognition process. The experimental results were carried out by using MATLAB and the training and testing success rates achieved by the developed system were 96.98% and 99.19% respectively. The experimental results demonstrated that the proposed system could be applied efficiently for LP recognition applications of Yemen licenses plates.

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