On-road Automobile License Plate Recognition Using Co-Occurrence Matrix

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Abstract: With the expansion of vehicles on the road in most recent decades, it is getting harder to monitor every vehicle in respect to law requirements and traffic management. The current license plate recognition methods have its own advantages and disadvantages. License plate tracking is used for activities such as automatic toll collection and criminal activity tracking. In this paper, a design and analysis of simulation model of an efficient vehicle license tracking system have been implemented using image processing technology by MATLAB. Vertical and horizontal projections and co-occurrence matrix have been used to program the numbers (0 to 9) and letters (A to Z) using MATLAB programming. In addition, segmentation and identification of the image features are implemented to recognize its text according to the co-occurrence matrix modeling.

Keywords: Plate Recognition, Co-Occurrence Matrix, Recognition algorithm, Simulation model.

1. Introduction

License plates are used to control, monitor, track, and identify moving vehicles. Another important application is the detection of the expiration date of the vehicle registration tags. The license plates information can be recognized and extracted from their images. This process can be organized according to the following algorithm:

1. Capture an acceptable resolution image for the license plate region
2. Pre-Processing the image (enhancement and noise reduction)
3. Number plate detection
4. Character localization and segmentation
5. Character recognition

Digital cameras capture colored images to be processed and prepared for next stages. The number plate recognition is a complicated process because of several reasons [1]. Typically, the number plate locations relatively occupy a small marginal portion from the entire image. Also, the number plates are in various colors, styles, and formats depending on the style of a country or state. There can be other factors affects the plate recognition efficiency such as; Uneven or low illumination, vehicle motion, blurry image, low image clarity resolution, distorted plate, dirty plates, shadowed plate, and reflection etc. Furthermore, several difficulties can be encountered in character segmentation, such as illumination deference, image noise, rivet, space mark, plate frame, and plate rotation [2]. As a result, characters could not be efficiently segmented causing character recognition accuracy to be decreased. Thus, in efficient characters segmentation will cause misrecognized or unrecognized characters. A pre-processing step should be added before detecting text to enhance the images and obtain accurate results[3]. Various techniques and methods have been proposed such as Otsu binarization method which is employed to segment the captured image into smaller sub-regions. However, binarization has been used to suppress backgrounds and highlight characters [4]. Also, various methods have been invented and used for different stages and purposes in the plate recognition systems such as; Pre-processing stage to minimize the processing time, Region of Interest (ROI) detection, improve the conditions of ambient illumination, increase the edge features, images noises removing, and image shadows reduction by transferring it to a binary image [5]. Thus, undoubtedly segmentation and recognition stages depend on the number plate extraction accuracy stage. As a result, this stage gained high research importance developing numerous techniques and methods to acquire accurate number plate detection. These number plate detection methods depend on: edge detection, texture, morphological processing, and histogram [6].Most of the research works have been surveyed, uses horizontal and vertical projections for characters segmentation stage and uses different types of Artificial Neural Network (ANN) for character recognition stage. Therefore, search window and artificial neural networks can integrate and combine to give the best recognition performance [7].

The method in [8, 9] relies on texture and edge information for number plate detection; it uses projection properties to detect the candidate number plate. However, a recent algorithm has been proposed considering edge detection based plate extraction. This method is relying on Line Grouping (LG) and Edge Density (ED) as an approach of car number plate extraction gives better results. In this method, the vertical and horizontal projections

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are performed by search window. Also, “Connected Component Labelling (CCL)” method is invented for plate detection. CCL scans captured image and labels the image pixels with respect to the pixel connectivity [10, 11].

2. The proposed work

Figure (1)depicts the flowchart of the stages of the proposed recognition system.

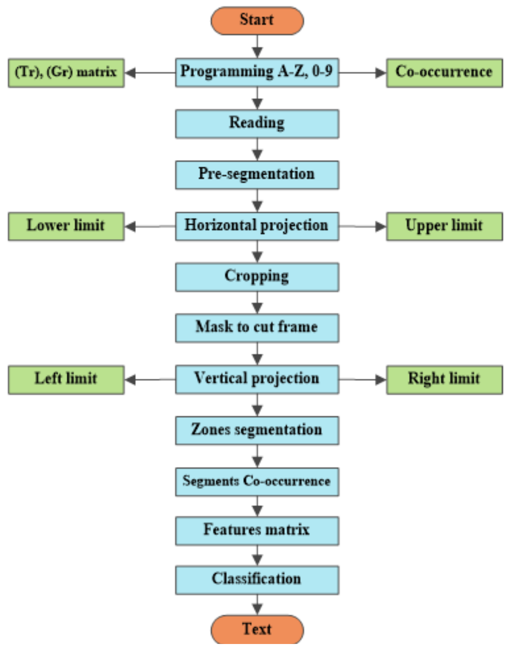

Figure 1: Flowchart showing license plate recognition algorithm in MATLAB

1 Programming A-Z & 0- 9 characters database

Several images have been selected for feature matching. Characters and numbers are extracted from those images. Some statistical features, such as energy, correlation, contrast, and homogeneity are calculated of the numbers (0-9) and characters (A-Z). Before obtaining the features, some pre-processing have to be applied for accurate results. Binarization and projection approaches are applied as a pre-processing step. Then, after applying all required processes to correct errors, finally, the database of each letter and number are saved in matrices for matching [12].

2 Co-occurrence matrix

An approach to analyzing texture of binary or gray level images statistically. It obtains the spatial connection of the grey level pixels and set them into a matrix. The functions of this matrix describe the distinctive features of the texture of an image through making calculations of how often a couple of pixel carrying particular values and in a certain spatial relationship takes a place in an image. Those calculations are used to create Gray Level Co-occurrence Matrix (GLCM). The statistical measures from this matrix are extracted. The functions of texture filtering could not provide shape information, which is the relationship of pixels in a grey level image [13].

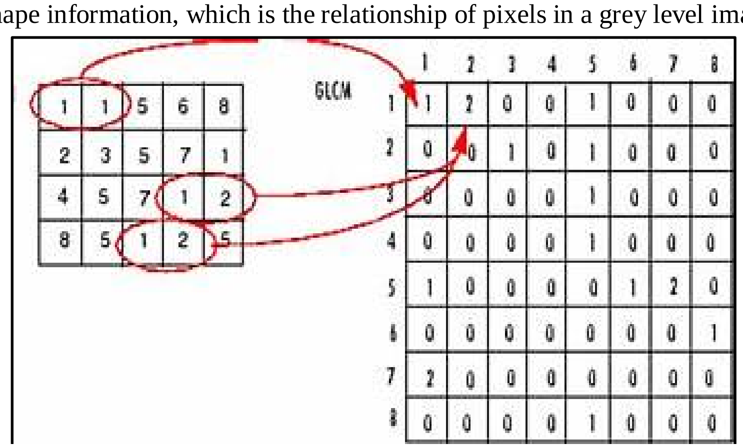

Figure 2:A gray value and it is co-occurrence matrix

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This matrix provides four statistics as follows:

1- Contrast: Measuring local distinctions of gray level images

$$\text{Contrast} = \sum_{i=1}^{Ng} \sum_{j=1}^{Ng} (i-j)^2 P_{ij} \quad (1)$$

2- Correlation: Measuring joint probability occurrence of the specified pixels pairs

$$\text{Correlation} = \frac{\sum_{i=1}^{Ng} \sum_{j=1}^{Ng} i \cdot j \cdot P_{ij} - \mu_x \cdot \mu_y}{\sigma_x \sigma_y} \quad (2)$$

where, σx,σyμx, and μy are the standard deviations and means of marginal probabilities Py(j) and Px(i) computed by summing up the columns or the rows of matrix Pij respectively.

3- Energy: it is the summation of squared elements in GLCM. It is also known as uniformly or the angular second moment.

$$\text{Energy} = \sum_{i=1}^{Ng} \sum_{j=1}^{Ng} P_{ij}^2 \quad (3)$$

where Pij is the ij entry of normalized co-occurrence matrix, Ng denotes the gray levels number of the video frame.

4- Homogeneity: Measuring the closeness of the allocation of elements in GLCM to its diagonal

$$\text{Homogeneity} = \sum_{i=1}^{Ng} \sum_{j=1}^{Ng} \frac{P_{ij}}{1+(i-j)^2} \quad (4)$$

3 Pre-segmentation (Convert a Colored Image into Gray Image)

It is the process of mapping a colored image into a binary image that represents the two digits 1 and 0 or in pixelating values 225 and 0 representing the colors black and white. Obtaining a binary image could be implemented by changing the colored input image, with RGB layout, into the greyscale layout. Thresholding is then used to convert the grey scale images to binary scale images. This conditional technique sets a threshold value, which is a grey scale value. This value then sets all pixels of the grey scale image that are less than its value into 0, while the rest of pixels become 1, which are black and white respectively. Finally, black foreground and white background or vice versa are obtained [14].

$$\text{F(x, y)} = \begin{cases} 0 & if\ K(x,y) < T \\ 1 & otherwise \end{cases} \quad (5)$$

Where, F(x,y)=pixel of binary image ,K(x,y) is pixel of gray image & T=threshold

4 Horizontal projection

Utilizing projections has not been a brand new idea. It, however, carries a new /distinct idea here is to locate the lower and higher constraints of a license plate according to the vertical edges received. This projection is carried out to obtain tops and bottom positions of interesting regions, which are the characters. Each projection bin has a magnitude of the summation of the white pixels alongside all traces within the horizontal path. Thus, the horizontal projection is acquired when all bins that are horizontally directed are computed. To locate the top and bottom bands, a threshold is been set according to the obtained mean value of the horizontal projection. Since the center location of the obtained horizontal projection is larger comparing to the recorded threshold, the highest and lowest bounds will be located to segment the projection and obtain the interesting areas, which are the exact characters, where the unwanted segments are cropped out [15].

$$H(i) = \sum_{i=1}^{x} B_{ij} \quad (6)$$

Where Bij is the discrete binary image with rows (i) and columns (j) where

[i= 0,1,2,...,y-1] and [j= 0,1,2….x-1], while H(i) denotes the horizontal projection.

5 Vertical Projection

Projecting vertically should be performed to obtain the spaces between characters on a car plate. Each projection bin has a magnitude of the summation of the white pixels alongside all traces within the vertical path. Thus, the

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vertical projection is acquired when all bins that are vertically directed are obtained. Then, according to the previous step of obtaining the vertical projection, each connected component or an area that has the same type of pixels will be separated with locations where the vertical projection is zero. Thus, the regions of interest, which are the license plate characters, will be separated. This process trims the upper and lower boundaries of images regarding the upper and lower edges of the wanted region before the areas beyond those bounds are cut. Applying this projection is to assure acquiring the zero values that are used to split the characters [15].

$$V(j) = \sum_{j=1}^{y} B_{ij} \quad (7)$$

Where Bij is the discrete binary image with rows (i) and columns (j) where [i= 0,1,2….y-1] and [j= 0,1,2….x-1], while V(j) denotes the vertical projection.

3. The Result and Discussion

1 Programming Database

Prior to implementing license plate recognition algorithm, database programming of the letters and numbers has been prepared using co-occurrence matrix. This modeling matrix saves the features of the letters (A-Z) and the numbers (0-9) in a matrix database form. For example, the license plate numbers in the figure (3)can be a possible plate number that a recognition system is designed to detect.

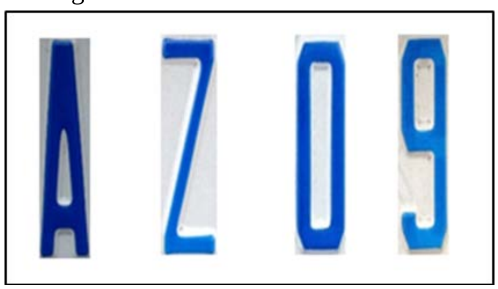

Figure 3: Samples of the used database

Each character should have acceptable dimensions and clarity to be detected for the above figure the characters have the following dimensions; the width is 258 pixels, and the height is 714 pixels

2 Colored to Gray Image Conversion

The algorithm does not react with colors of the numbers in the processed image. However, it depends only on the level of gray color to process the image and extract required data. As a result, colors like red, green and blue, which is widely used in the plates numbers, cannot be used in this model. Thus, input colored image represented of three dimensions array must be first converted to two dimensions gray image. Afterward, further processing can take over to detect the plate information. Figure (4) illustrates an original input colored sample image and its gray image copy. The input image has the following dimension; the width is 512 pixels, the height is 275 pixels

Figure 4: Original colored plate image and gray conversion

3 Pre-segmentation

This process can be implemented into two steps Horizontal Projection and Vertical Projection. Horizontal projection can be found algorithm navigates through the columns of the tested image. Thus, the algorithm begins with the second pixel from the top for each column. Then the variation between first and second pixel is computed. If the variation surpasses beyond a certain predefined threshold then it is added to so-called total differences

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summation. Similarly, the algorithm moves downwards sequence calculating the difference between the second and third pixels and so on. It continues moving until ending the columns and calculates total differences summation between adjacent pixels. As a result, a matrix, containing column wise number of bins summation, has been extracted as shown in figure (5).

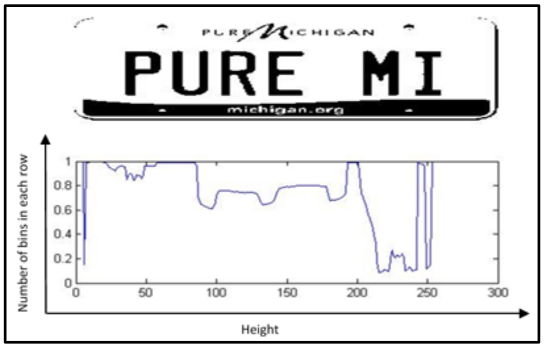

Figure 5: Horizontal projection column-wise sum

After implementing column-wise horizontal projection, the image must be rotated by a 90° angle to find its vertical projection to prepare it for the next step, which is the segmentation.

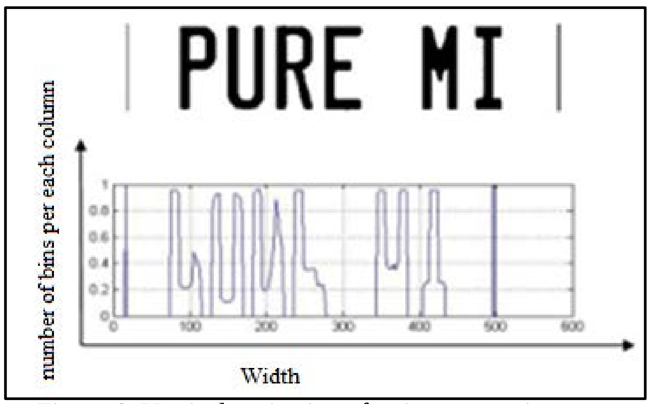

Figure 6: Vertical projection after image rotation

4 Segmentation

Prior to segmentation stage, the regions of interest extraction from the plate must be identified. Thus, the segmentation can be processed on several regions with a probability of containing the plate. The region with the maximum value is nominated as a number plate possible. Thus, all regions in the initial captured image are processed column-wise then row-wise to locate a common spot has highest vertical and horizontal projection values. In figure (7), the detected interesting regions that have maximum probability license plate location.

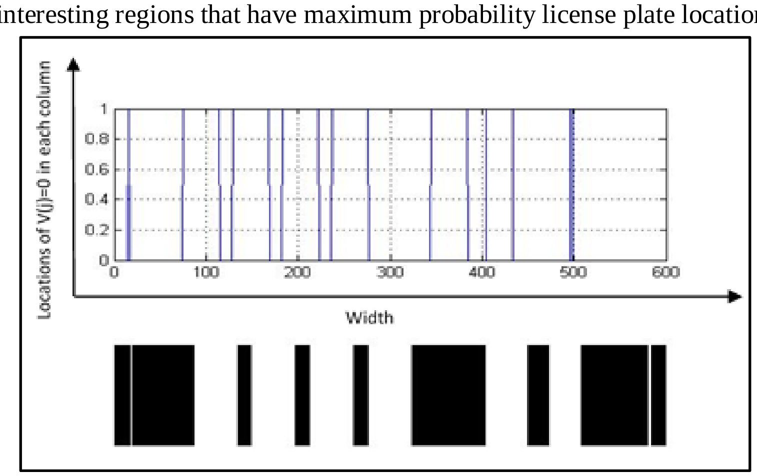

Figure 7: Segmentation Mask

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In this stage, all image regions with high probability of license plate positioned are located. Also, coordinates of these high probability regions are stored in form of an array. In figure (8) depict the output image displaying high probability license plate regions after applying the segmentation mask to crop the frame and detect the characters zones by finding the first-row derivative of the mask.

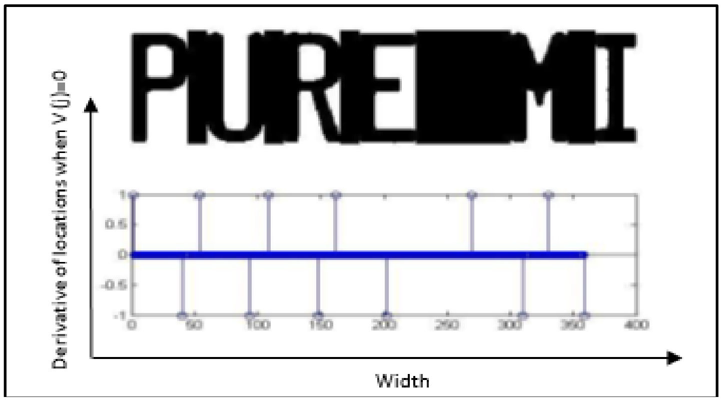

Figure 8: The high probability license plate regions after segmentation mask

Afterward, applying the result on MATLAB model, an editable text of the outcome plate number image is found, as shown in figure (9)

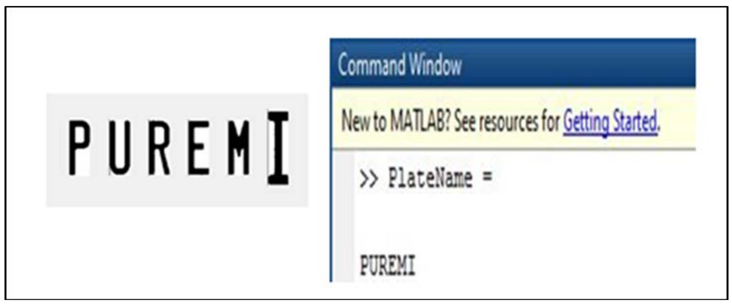

Figure 9: The segmented characters and the resulting text

4. Conclusion

In this research work, an on-road vehicles plate recognition method is implemented and analyzed using Co-occurrence matrix method. Firstly, the automobile plate photo is captured by digital cameras, then the image undergoes a processing stage to extract plate's information. Afterward, vertical projection, horizontal projection, and gray level Cooccurrence are implemented by a MATLAB model to extract the editable text of the extracted plate's information. While this paper focused on recognition stage, yet segmentation and text classification stages should be enhanced and operated in an integrated system to achieve higher operation reliability in more complicated operation scenarios. The future research work will concentrate on enhancing and optimizing the outcome of current recognition method exploiting novel segmentation approaches with advanced features.

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