Chapter 4

Vehicle Number Plate Extraction and Recognition

4.1 Introduction

During recent years, the VNPR system has been widely used as a core technology for security or traffic applications such as in traffic surveillance, parking lot access control, and information management [73, 87]. VNPR helps to identify and register vehicles and provide the reference for further vehicle tracking and activity analysis [160]. In VNPR, we need to deal with a large variety of license plates. They are different with respect to colour, shape, size, and patterns. Another challenge in VNPR is that the image quality taken by camera in real time may be affected by severe weather conditions, poor lighting conditions, and low camera resolutions. The aperture time of the camera will cause the blurring effect of the moving vehicle. The third challenging issue we need to address in VNPR system is the large variations in camera perspectives when the license plate image is captured. A number of approaches were proposed: Lotufo *et al.* [161] used optical character recognition techniques for automatic number-plate recognition. Abolghasemi and Ahmadifard [162] used IFT-based fast method for extracting the license plate. Zamani *et al.* [163] used morphologic method for extracting the

* The entire chapter in the form of paper has been accepted in "IEEE Computer", 2014.

license plate. But all these are valid for particular cases with some constraints [49, 164, 165]. There are also some VNPR systems that are installed on the road [55-166]. This chapter describes a newly proposed method for VNPR using Daubechies wavelet transform that overcome the current limitations and gives rewarding results.

4.2 Related Works

In most cases, License Plate Localization is a necessary procedure before VNPR. The methods to locate the license plate region in images or videos from previous literature can be grouped into the following categories: Binary Image Processing, Gray-Level Processing, Color Processing and Classifiers [87]. Character segmentation is also a very important step before character recognition. The methods for character segmentation can be grouped into Binary Image Processing, Grey-Level Processing and Classifiers. To recognize the segmented characters, a number of algorithms using the pattern/template matching or learning based classification have been developed [83].

4.2.1 Binary Image Processing

To extract license plate regions from background images, techniques based on combinations of edge statistics and morphology can achieve good results. Hongliang and Changping [167] applied edge operators on a grey image after smoothing and normalization to extract horizontal and vertical edge maps. Statistical analysis of edges was then performed to detect the rectangle of license plate. The final decision was made based on the connected component analysis (CCA). They claimed that their algorithm can achieve 99.6% detection rate from 9825 images. But these methods are based on the hypothesis that the edges of the license plate frames are clear and horizontal. Lim and Tay [98] used maximally stable extremal regions to obtain a set of character regions. This method of extracting character from the binary image, defining license plate region, is time consuming because the method process all binary objects. Further, it gives wrong identification when there is other text in the image.

4.2.2 Grey-Level Processing

In [116], the authors exploited contrast between the characters and the background. Similarly, in [55], blocks with high edge magnitude and variance are considered as the license plate region. Image transformation methods based on Hough transform and Gabor filters have also been applied in license plate detection. Hough transform is a classic algorithm to detect straight lines. However, this method is valid only when the background of the image is simple. Another disadvantage of this method is that the computational complexity of Hough transform is very high. Gabor filters are often used to analyse textures.

4.2.3 Color Processing

In many countries, the color of the text and background of the license plate is strictly fixed. Hence many algorithms have been proposed assuming this constraint [168-167], which fails under varying lightening conditions because in such cases the color of license plate varies. The accurate plate location is fundamental to the success of the whole recognition process. Some papers propose the use of color features to localize the plate [168]. However it fails when plates have many possible colors. Chou *et al.* [169] proposed an approach for plate recognition that is based on matching of vertical edges but this approach fails on varying plate size and also when the color contrast of plate and car body is poor. Further it works on Saudi Arabian plates. Wang *et al.* [170] used a methodology of horizontal scan of repeated contrast changes, for plate recognition. Fully connected feed forward artificial neural network with sigmoidal activation functions has been used for character recognition. The limitation of this approach is that the number plate identification rate is only 80% and processing time is 15 seconds. Further it works for Indian plates. In [171], a license plate detection method based on sliding concentric windows and histogram was proposed but it is suitable only for Taiwanese plates and is time consuming. Chen *et al.* [172] combined the rectangle shape feature, the texture feature, and the color feature to extract the license plate. Its success rate is 97.3% but computationally complex and hence takes more computation time. In [173], a method based on dynamic programming was described for extraction of license plate numbers but the success rate of segmentation is only 84.5%.

4.3 The proposed method

We propose a framework for VNPR, which contains three phases as shown in figure 4.1.

Figure 4.1: VNPR framework

The phases are described as follows.

4.3.1 Image Capture and pre-processing

In this phase the image of the vehicle is captured and normalized to standard dimensions of 400×300 pixels. Then we convert this RGB colored image into 256 greyscale image using equation 4.1 [174].

$$A_{GL} = \frac{3A_R + 6A_G + A_B}{10} \tag{4.1}$$

Here A_{GL} is converted into grey level image. A_R,A_G and A_B are R,G,B spectrum of the color image respectively. Original Image,A_R,A_G and A_B are shown in figure 4.2(a), figure 4.2(b), figure 4.2(c) and figure 4.2(d) respectively.

4.3.2 License plate localization

The accurate plate location is fundamental to the success of the whole recognition process. Some papers propose the use of color features to localize the plate [168]. However it fails when plates have many possible colors. We took A_B as our candidate for plate localization. We use wavelet decomposition of A_B to compute the approximation coefficients matrix and details coefficients matrices. The result is shown in figure 4.3. These four frequency bands represent low-frequency, horizontal frequency, vertical frequency and diagonal frequency energy respectively. With

Figure 4.2: (a)Original Image (b)A_R (c)A_G (d)A_B

respect to the license plate localization, the energies of horizontal and vertical frequency can locate the license plate because the number plate has high frequency. Hence for finding the vertical location of the plate, we plot the energy curve of the pixel intensity of each row of the vertical frequency band. Similarly for finding the horizontal location of the plate, we plot the energy curve of the pixel intensity of each column of the horizontal frequency band. The plots are shown in figure 4.4 (P-53).

The grey image of figure 4.3(a), figure 4.3(b), figure 4.3(c) and figure 4.3(d) is shown in figure 4.5(a), figure 4.5(b), figure 4.5(c) and figure 4.5(d) respectively. The minimum value of image is displayed as black, and the maximum value is displayed as white.

A Gaussian filter modifies the input signal by convolution with a Gaussian function. Its impulse response is a Gaussian function. The one-dimension Gaus-

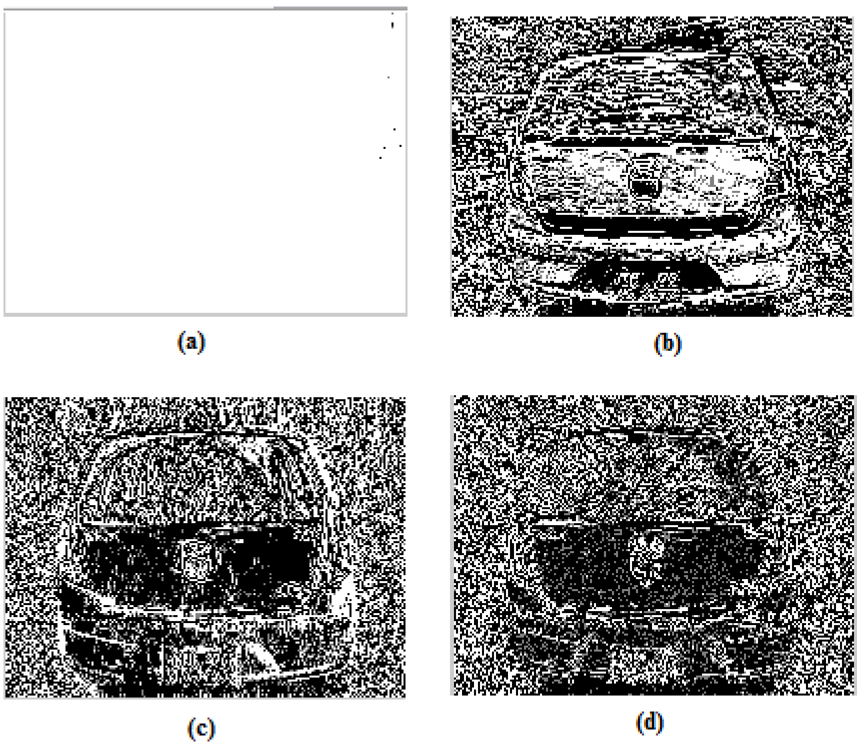


Figure 4.3: Single-level discrete 2-D wavelet transform of A_B.

sian filter has an impulse response given by equation 4.2.

$$g(x) = \sqrt{\frac{a}{\pi}} e^{-ax^2} \tag{4.2}$$

and the frequency response is given by equation 4.3.

$$\hat{g}(f) = e^{-\frac{\pi^2 f^2}{a}} \tag{4.3}$$

where f is the ordinary frequency. These equations can also be expressed with the standard deviation σ as parameter equation 4.4

$$g(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-x^2}{2\sigma^2}} \tag{4.4}$$

and the frequency response is given by equation 4.5.

$$\hat{g}(f) = e^{-\frac{\pi^2 f^2}{2\sigma_f^2}} \tag{4.5}$$

The advantages of Gaussian filtering is that it is rotationally symmetric; filter weights decrease monotonically from central peak, giving most weight to central pixels; simple and intuitive relationship between size of σ and the smoothing; it is separable. The advantage of separability is that it first convolves the image with a one dimensional horizontal filter, and then convolves the result of the first convolution with a one dimensional vertical filter. For a $k \times k$ Gaussian filter, 2D convolution requires k^2 operations per pixel. But using the separable filters, we reduce this to 2k operations per pixel.

Therefore, for smoothing the curve, we apply Gaussian filter on both the energy curves, the results are shown in figure 4.6 (P-55). The high energies of the vertical frequency curve represent the number plate because as earlier mentioned; we find more frequency at the location of the number plate.

To compute the high energy frequency band, we compute a threshold value to operate on the vertical and horizontal frequency energy curves. We take the half of the maximum vertical energy and traverse from left to right and right to left direction in the vertical frequency curve to compute the y coordinates. The y coordinates that are greater than the threshold value represents the vertical location of the plate. The result is shown in figure 4.7 (P-56).

For accurate measurement of the horizontal location, rather operating on the horizontal frequency energy curve, shown in figure 4.6, we perform the operation on the figure 4.7. The reason is, if we traverse from left to right direction in figure 4.7, we observe that the frequency is more at the location of the number plate. Hence, to find the horizontal location, we repeat the process as we have done for finding the licence plate vertically. We again take the single-level wavelet transform of the figure 4.7 and plot the energy curve of the pixel intensity of each column of the horizontal frequency band. Again we apply the Gaussian filter for curve smoothing. The result is shown in figure 4.8 (P-57). It should be noted that here we don't need the half of maximum y coordinate to compute the threshold value, because the frequency is very high at the location of the number plate as compared to other locations. We take 0.9 times the maximum value to compute the threshold value and traverse from left to right and right to left direction to compute the x coordinates. The result is shown in figure 4.9 (P-58). Also, some adjustments may be required to compute the threshold values for horizontal and vertical location.

4.3.3 Number recognition

For number recognition, we first convert the extracted grey colored plate, shown in figure 4.9 into black and white image. For this we set the pixel intensity to 255 and 0, whose pixel intensity is greater or equal to and less than 128 respectively. The result is shown in figure 4.10 (P-58).

The next step is character segmentation. For this we follow the same process of doing wavelet decomposition of extracted binarized plate. The result is shown in figure 4.11 (P-58).

We know that the numbers are written line-wise. Normally, there are only two lines. To separate the lines, we plot the energy curve of the vertical frequency of figure 4.10, as shown in figure 4.12 (P-58). Just to visualize the energy curve of the horizontal frequency of figure 4.10, we have shown it in figure 4.13 (P-59). Number of sub-curves that starts and end with 0, represents the number of lines in the license plate. The result is shown in figure 4.14 (P-59).

Now for character segmentation, we plot the energy curve, column wise of figure 4.14. The plot for the first line is given in figure 4.15 (P-60). Smoothing of this curve is not required because the gray image has been converted into black and white image. The area between the points at which the curve starts falling towards x axis represents a single character. The segmented characters are shown in figure 4.16 (P-60). We have taken a margin of 1 pixel on both the sides of a character.

After segmentation process, the characters need to be normalized to refine the characters into a block containing no extra white spaces (pixels) in all the borders of the characters. Then each character is resized to 38×20 block. For template matching, fitting approach is necessary. To match the characters with the database, input image of segmented characters must be equalized to a 38×20 block with the database characters. Next step is template matching, which is an effective algorithm for recognition of characters. The segmented characters are compared with the characters that are in the database and the best match is considered. We use a statistical method correlation based method to find the best match. This method measures the correlation coefficient between the unknown images and known images. The highest correlation gives the best match. We use database of 36 alphanumeric characters (26 alphabets and 10 numbers) with the size of 38×20. There may be some errors during the recognition phase because of similarities in some characters like 'O' and numeral '0'. To reduce the error further, some special properties of each character are used.

4.4 Experimental Results

Experiments have been performed to test the proposed technique for licence plate localization and recognition and to measure the accuracy. The input images are colored images with the size of 400×300 pixels. The test has been performed on 40 different models of cars having different shape, size and color and under varying lightning conditions and distance. On total 150 license images have been taken. The results are summarized in table 4.1.

4.5 Conclusion

In this chapter a technique for vehicle licence plate localization and recognition has been proposed. To ease the implementation, we have divided this task into three phases: image capturing and pre-processing; licence plate localization; number recognition. Number plate localization is the most challenging task faced by the computer science technology now a days. The major factors are varying lightening conditions, size, shape, color combination of text and number plates, location of the plate. We have used the single-level wavelet transform to deal with. The technique showed up to be efficient in varying conditions, and therefore is useful for real applications. To segment the characters, we used projection method and finally we use template matching technique for number plate recognition.

The results achieved by our technique are highly satisfactory. The plate localization technique achieved 97.6% of accuracy as shown in table 4.1(a), character segmentation technique achieved 97.8% of accuracy as shown in table 4.1(b) and character recognition achieved 96.0% of accuracy as shown in table 4.1(c). In table 4.2(P-52), we show the performance comparison of our technique with the existing

Table 4.1: Results of Plate Localization, character segmentation and character recognition.

	Quantity	**Percentage**
Total number of available images	250	100
Correctly found plate images	244	97.6
Images whose plates were found and they were only candidate region	218	87.2
Images whose plates were not found	6	2.4

(a) Results of Plate Localization.

	Quantity	**Percentage**
Total number of characters	2500	100
Successfully segmented characters	2445	97.8
Unsuccessfully segmented characters	105	2.2

(b) Results of character segmentation.

	Quantity	**Percentage**
Total number of characters	2500	100
Successfully recognized characters	2400	96.0
Unsuccessfully recognized characters	100	4.0

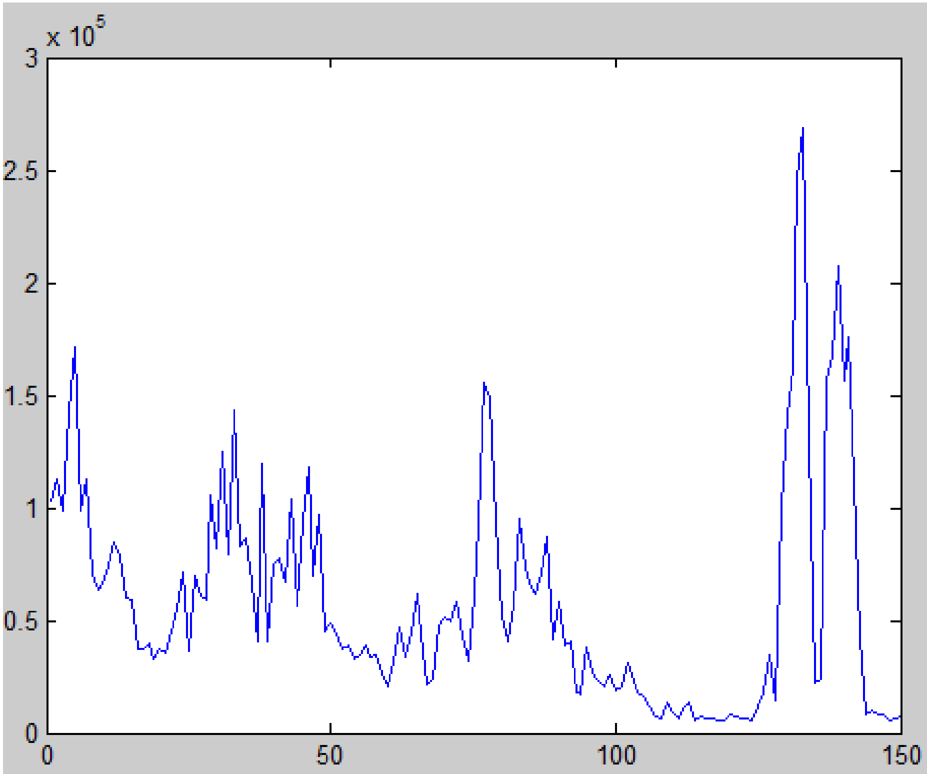
(c) Results of character recognition.

techniques.

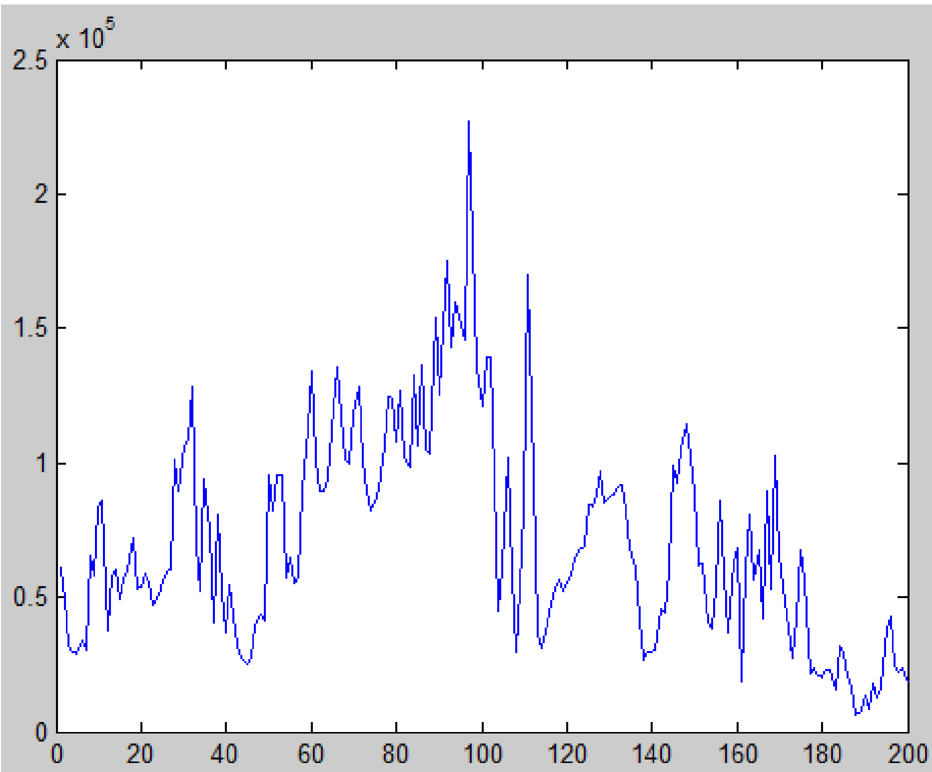
These results show the effectiveness of the new proposed technique and make them suitable to deal with the real world applications.

Table 4.2: Performance comparison of some existing VNPR systems.

Methods	**Plate Localization Rate**	**Character segmentation Rate**	**Character Recognition Rate**	**Total Rate**
[169]	96.20%	—	—	95.00%
[170]	99.00%	—	98.00%	80.00%%
[171]	92.40%	—	—	—
[173]	—	84.50%	—	—
Our method	97.6%	97.8%	96.00%	96.40%



(a)



(b)

Figure 4.4: (a) Vertical frequency energy curve (b) Horizontal frequency energy curve

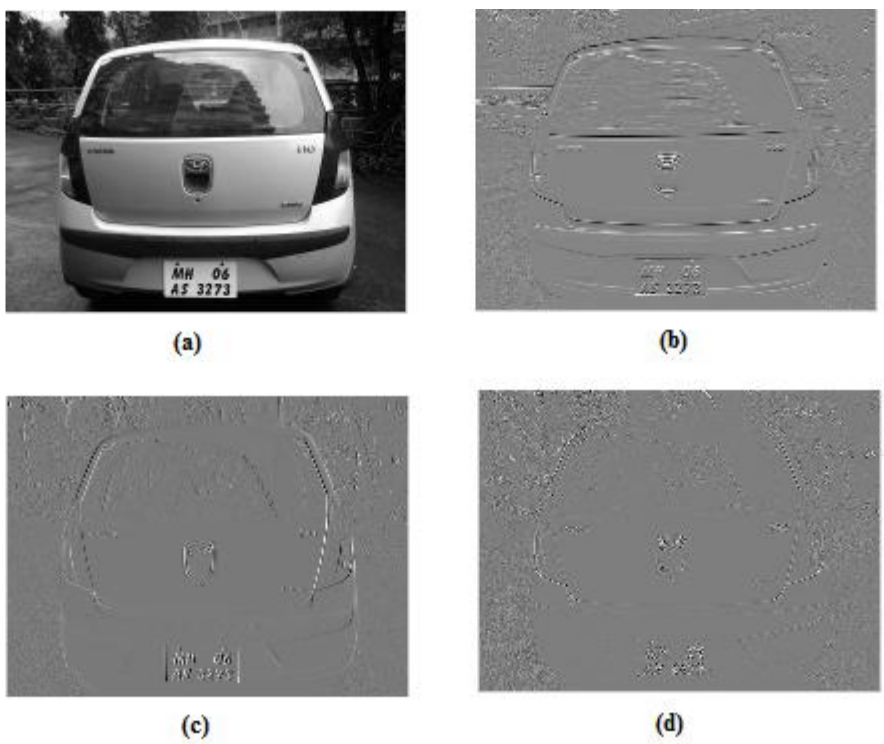
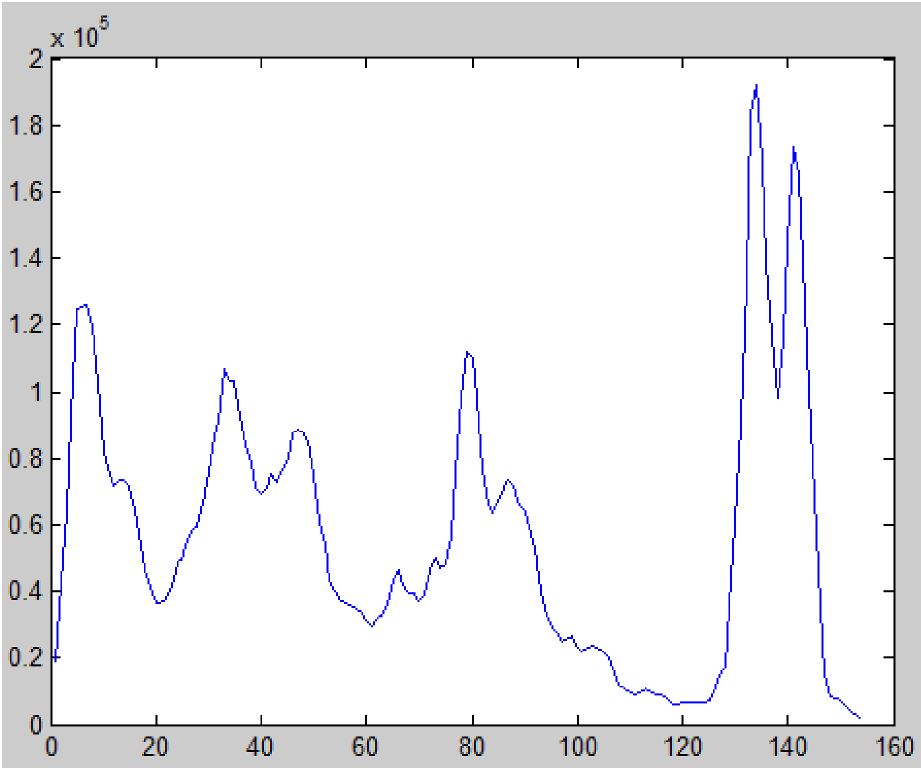
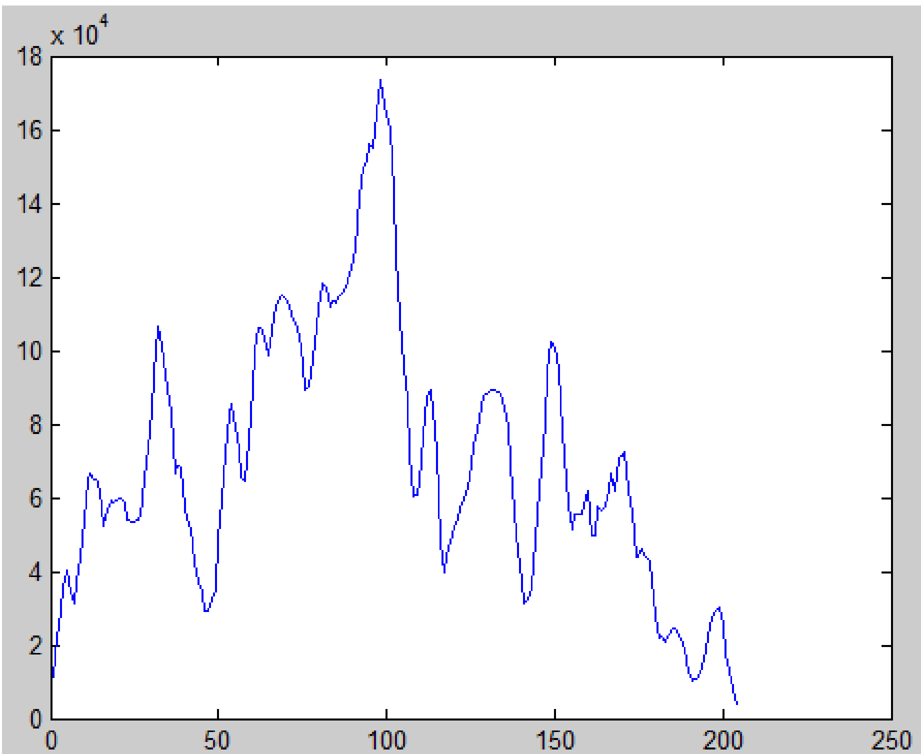


Figure 4.5: (a) Grey image of figure 4.3(a). (b) Grey image of figure 4.3(b). (c) Grey image of figure 4.3(c). (d) Grey image of figure 4.3(d)



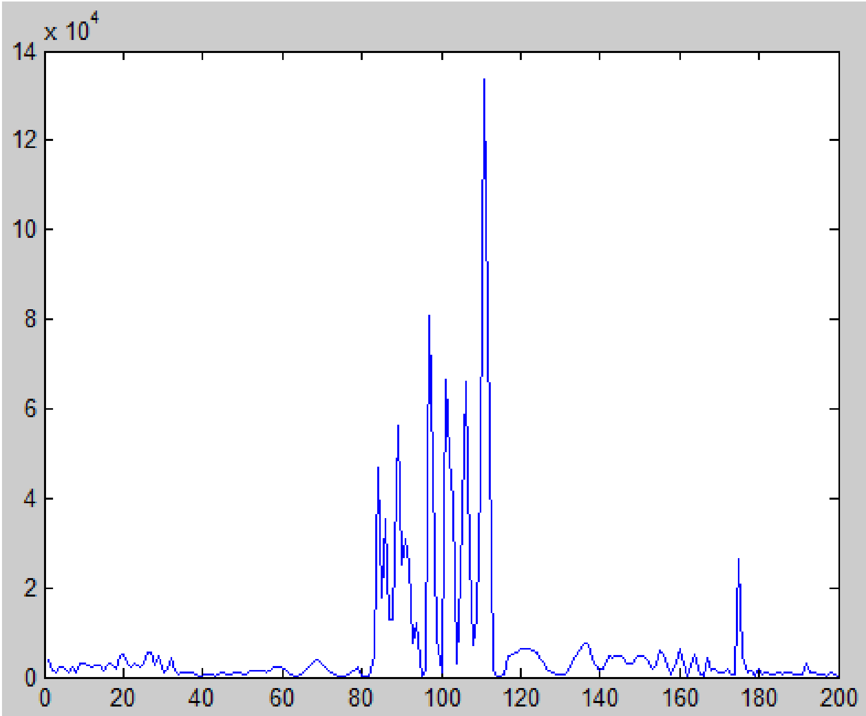
(a)



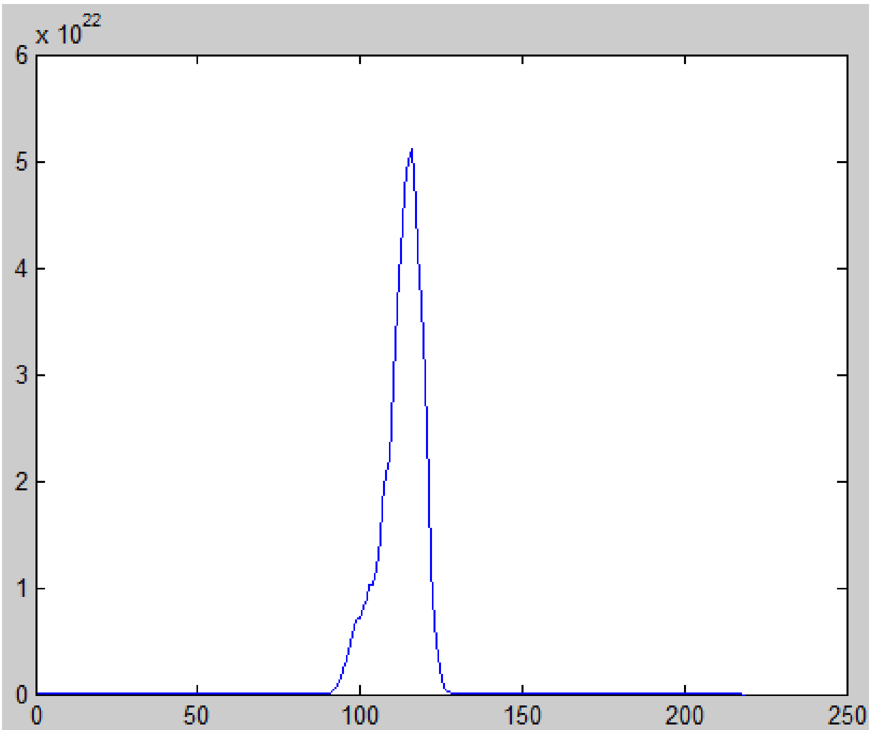
(b)

Figure 4.6: Smoothing of: (a) Vertical frequency energy curve (b) Horizontal frequency curve

Figure 4.7: Plate Location vertically



(a)



(b)

Figure 4.8: (a) Energy curve of horizontal frequency energy of figure 4.7. (b) Its smoothing curve

Figure 4.9: Plate Localization

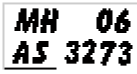


Figure 4.10: Plate Binarization

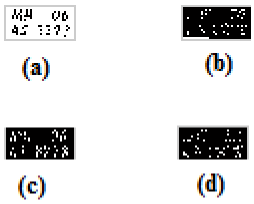


Figure 4.11: Single-level discrete 2-D wavelet transform of figure 4.10

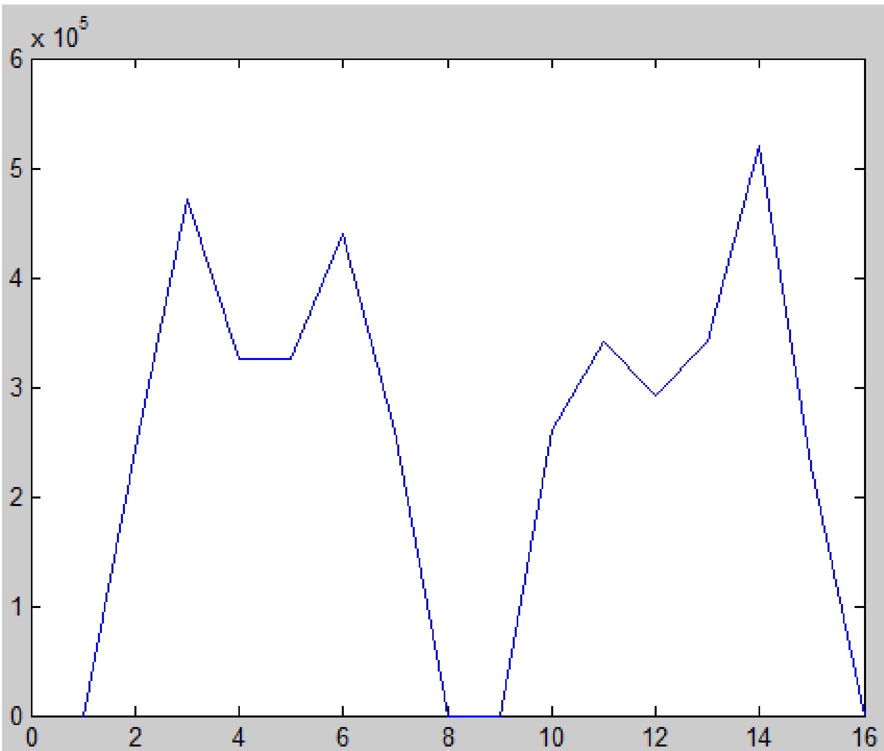


Figure 4.12: Energy curve of vertical frequency of figure 4.10

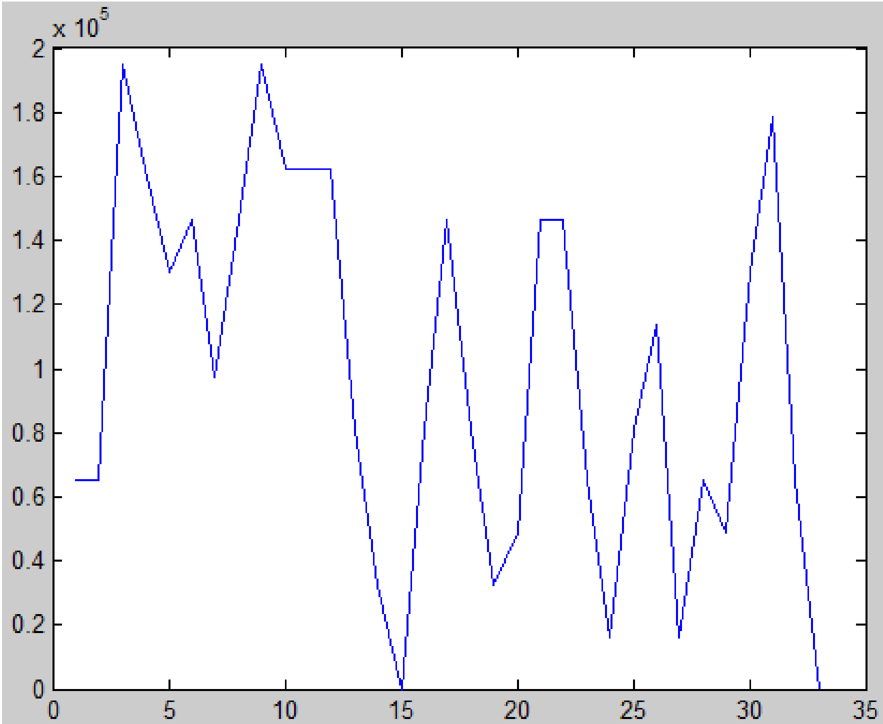


Figure 4.13: Energy curve of horizontal frequency of figure 4.10

(a) **(b)**

Figure 4.14: Line Split in license plate

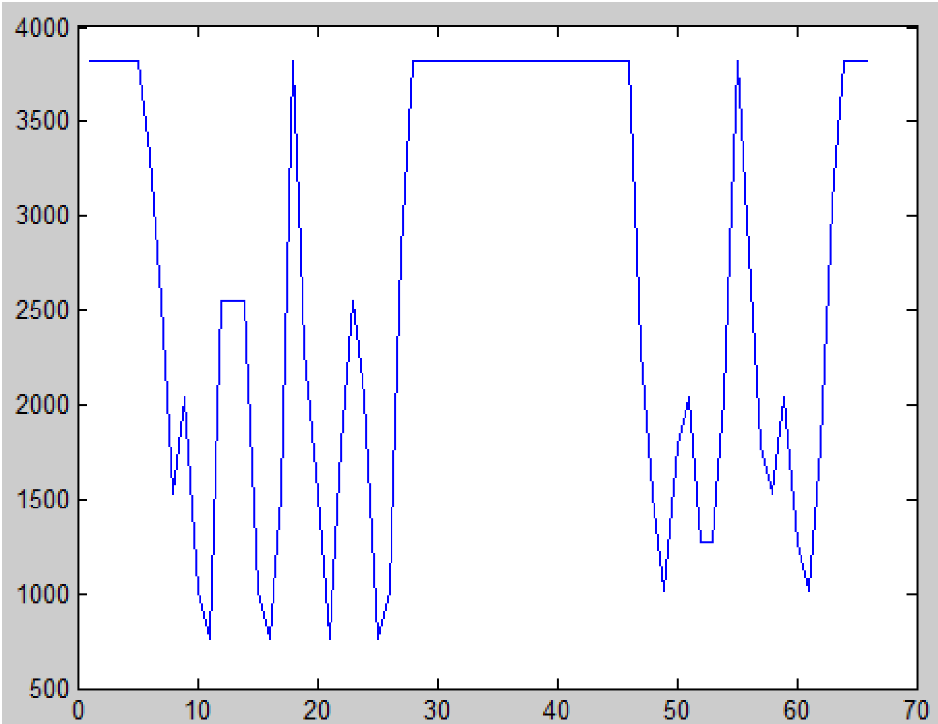


Figure 4.15: Energy curve of figure 4.14 a column wise

Figure 4.16: Segmented characters