Abstract— Bangladeshi vehicle digital license plate recognition system using support vector machine for metropolitan cities (i.e. Dhaka, Chittagong) is presented in this paper. The proposed system divided into three major parts- license plate detection, plate character segmentation and character recognition. Experiments have been done for this proposed framework. More than 1000 images taken from various scenes are used, including diverse angles, different lightening conditions and complex scenes. In the first phase, Sobel operator and histogram analysis is used to detect the license plate region. Then, connected component labeling and bounding box technique used to segment the characters of detected license plate region. After that, Gabor filter is applied on the segmented characters to acquire desired character features. Since feature vector obtained using Gabor filter is in a high dimension, to reduce the dimensionality a nonlinear dimensionality reduction technique that is Kernel PCA has been used. Finally, Support Vector Machine has been used for classification. The experimental results show that proposed method can correctly recognize the license plate characters.

Keywords-vehicle digital license plate detection; morphology; Sobel operator; connected component labeling; Gabor filter; Kernel PCA; Support Vector Machine.

I. INTRODUCTION

License Plate Recognition (LPR) is a vital research area due to its applications. The task of recognizing specific object in an image is one of the hardest topics in the field of computer vision. For license plate character recognition we can employ existing closed-circuit TV or road-rule enforcement cameras. License plate recognition can be used in many application such as electronic toll collection on pay-per-use roads, parking or exit managing and traffic control and management. Vehicle Retro-Reflective license plate commonly known as Vehicle digital license plate, the most current and technically improve license plate ever in Bangladesh. Government of Bangladesh has a goal to turn the country digital within 2021. As a part of digitalization, BRTA (Bangladesh Road Transport Authority) has introduced the Retro-Reflective license plate generally known as digital license plate.

The vehicle license plate recognition task is quite challenging from vehicle images due to the view point changes, and the non-uniform outside illumination conditions during image acquisition. In this paper we have used a database, which contains complex images. In the database, images also taken in different background, illumination and distance between the vehicle and camera is also different. This paper proposes a framework for Bangladeshi digital license plate recognition. The framework composed of three processing steps: 1) license plate detection by morphological processing; 2) segmentation of plate characters by connected component labeling and bounding box and 3) recognition of each character by extracting the features from the character and then recognizing by SVM classifier.

In segmentation phase, our method focuses on a solution for image disturbance resulting from non-uniform lighting condition and several outdoor conditions such as shadow. Additionally, our approach has numerous inherent advantages over other feature extraction technique. Our proposed framework is almost independent of slant or skewness. In feature extraction phase, features are extracted from the characters by Gabor filter, which is invariant to non-uniform lighting condition, rotation, scaling, and translation. Then Kernel PCA is used to reduce the high dimensionality of feature vector that is obtained by Gabor filter. Finally, SVM classifier is used to recognize the characters. The experiment results demonstrate a maximum recognition rate of 99.2%. Moreover, our experimental result also compared with previous works conducted for the recognition of Bangladeshi license plate.

The paper is organized as follows. The next section contains a review of related researches that have been implemented. Proposed framework is described in section III. Section IV presents results evaluation. Finally, conclusion is given in section V.

II. RELATED WORK

Different techniques are developed for license plate extraction. This section presents some previous related works for license plate detection which is significant to proposed approach.

Raiyan Abdul Baten et al [1] proposed a simple method for license plate recognition of Bangladesh using template matching. Here the authors briefly describe the characteristics of license plate in the metropolitan cities of Bangladesh. In [2],

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morphological technique used for recognizing the characters. In [3], HSI color model and geometrical properties used by the authors to detect the Bangladeshi vehicle license plate. In [4], authors proposed Bangla automatic number plate recognition system using artificial neural network. A robust feature extraction technique is applied to extract the feature from each character which is invariant to the rotation and scaling.

In [5], a novel adaptive image segmentation method named as sliding concentric windows used for detecting license plate region. Kaushik Deb et al [6] proposed an efficient method using sliding concentric windows and artificial neural network to recognize the license plate. In [7], morphological processing and support vector machines used to recognize the license plate characters with an average accuracy of 97.89%. Morphology and least squares support vector machines used to recognize the license plate in [8]. In [9], edge detection and morphological processing used for license plate detection. Support vector machine used to recognize Chinese license plate in [10] with an average accuracy of 96.3%.

III. PROPOSED FRAMEWORK

The proposed vehicle license plate recognition algorithm consists of three main stages: (1) detecting candidate region (2) character segmentation and (3) character recognition. The block diagram in figure 1 shows the working approach towards the solution of the stated problem.

A. RGB to Gray scale conversion

The vehicle with digital license plate is first captured using digital camera and stored in jpg format. More than 1000 images taken from various scenes were used, including complex scenes, diverse angles and different lighting conditions. The size of the input images is 640×480 pixels. Figure 2 shows a capture image of vehicle with digital license plate.

The RGB color model consists of the three additive colors: red, green, and blue. This process converts the RGB image into gray scale image. We require to do this conversion because we will perform edge detection operation on gray scale image. The resulting gray scale image will be in two dimensional. The range will be among 0 to 255 values. The value 255 represents pure white and 0 represents pure black. Figure 3 shows RGB to gray conversion result. Conversion is done using weighted sum method as

\[
GI = 0.2990R + 0.5870G + 0.1140B
\]  

B. Edge Detection

An edge represents the border line of an object which can be used to detect the shapes and area of the particular object. A license plate region contains many vertical edges due to characters and numbers. Many methods have been proposed for edge detection [2, 9-10]. We selected the sobel operator for finding the license plate region in an image because it produced better results and it also works faster compared to other gradient operators. Sobel filter creates an image which emphasizes edges and transitions. There are two masks for sobel filter, one
is horizontal mask and another one is vertical mask. Vertical mask will find the edges in vertical direction, it is because the zeros column in the vertical direction. Horizontal mask will find edges in horizontal direction, as zeros column is in horizontal direction. Here we used sobel vertical mask as we need vertical edges. The result of edge detection is shown in figure 5.

<table>
<thead>
<tr>
<th>-1</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>-1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

| -1 | -2 | -1 |
| 0  | 0 | 0 |
| 1  | 2 | 1 |

Fig. 4. (a) Sobel vertical mask and (b) Sobel horizontal mask

Fig. 5. Vertical edge detection

C. Gray scale image to Binary image conversion

Then the gray scale image is converted to a binary image. A binary image is a digital image that has only two possible colors (i.e. black and white) for each pixel. Here we used Otsu method [11] to convert the processed image to binary image.

Fig. 6. Binary image

D. Histogram Analysis

Vertical projection refers to find out the sum of pixels in each column of an image. And horizontal projection refers to find out the sum of pixels in each row of an image. Here, histogram analysis had done to find the vertical projection of the processed binary image. In vertical projection, y-axis is the rows of the image, and x-axis shows the number of white pixels in each row. Figure 7 shows the resulted vertical projection of the binary image in figure 6. In the vertical projection, the rows parallel to the license plate region generally have the maximum values. Then based on a threshold value $t$, we find out the rows with the maximum values in the vertical projection.

Fig. 7. Vertical projection of the binary image

E. Dilation

Morphological operations apply a structuring element to an input image, producing an output image of the same size. The most fundamental morphological operations are dilation and erosion. Dilation inserts pixels to the borders of objects in an image, while erosion removes pixels on object borders.

The dilation of object $A$ by structuring elements $B$ can be defined by:

$$ A \oplus B = \bigcup_{b \in B} A_b $$

Here we first dilated the processed image horizontally and then vertically. From these two dilated images we find out the common white pixels. Again dilation operation is applied on the processed binary image. The structuring element for all dilations are rectangles. The probable holes are filled as we want to get a continuous area for license plate region. The result of dilation is shown in figure 8.

Fig. 8. (a) Image after Horizontal dilation, (b) Image after Vertical dilation (c) Image after dilation process (d) Image after Erosion process
F. Erosion

Erosion operator excludes any extra regions, which do not belong to the plate. The erosion of the binary image $A$ by the structuring element $B$ can be defined by:

$$\mathcal{A} \ominus B = \bigcap_{b \in B} A_{-b}$$ (3)

Here we erode the processed binary image with a horizontal line. The result of erosion is shown in figure 8(d).

G. Labeling and Filtering

Connected-component labeling is used in computer vision to identify connected regions in binary digital images. Next step is to find biggest binary region. For this first we find out the number of connected regions using connected component labeling [12]. Then we compute the area of every regions and find out biggest binary region i.e. license Plate. Based on a threshold value we enlarge the candidate region due to Bangladeshi license plate contains two lines of characters and digits. Figure 9 shows the detected license plate region. Then license plate region is extracted from the image by using image crop function from the MATLAB.

Fig. 9. Detected license plate region

H. Character Segmentation

Character segmentation is a process that seeks to decompose an image of a sequence of characters into sub-images of individual symbols. Here the extracted candidate region image is a RGB image. After extracting the candidate region, image is converted to binary image using adaptive thresholding.

![Fig. 10. (a) Input image; (b) Extracted license plate; (c) Binary conversion by traditional method; (d) Binary conversion by adaptive thresholding](image)

Adaptive thresholding is used to overcome non-uniform illumination problem. Due several outdoor conditions, shadow may appear in the license plate region during image acquisition, which are usually challenging for obtaining successful processed results using traditional binary techniques. The result of adaptive thresholding is compared with traditional binary conversion method (i.e. Otsu method) in figure 10. The whole process of adaptive thresholding algorithm consists of several steps:

1. Convolution operation is performed on the image by using a suitable statistical operator, i.e. mean.
2. Deduct the original image from the convolved image.
3. Threshold the difference image with $C$ (i.e. $C$ is a constant).

Once the candidate area is binarized the next step is to segment the characters. At first, Remove all object containing fewer than 30 pixels to eliminate regions without interest such as small noisy regions. Then we label connected components in candidate region. After that we measure a set of geometrical properties such as bounding box and aspect ratio for each connected components (object) in the binary image. Finally, characters are extracted from the candidate region by aspect ratio. The aspect ratio [3] can be found by the ratio of width and height of the bounding box of an object. The aspect ratio is defined by,

$$AR = \frac{(C_{\text{max}} - C_{\text{min}}) + 1}{(R_{\text{max}} - R_{\text{min}}) + 1}$$ (4)

Where $C$ and $R$ indicate columns and row, respectively. Objects which satisfy $AR$ (aspect ratio) bounds 1 to 2 are considered as candidate characters. The result of character segmentation is shown in figure 12.

Fig. 11. (a) candidate region and (b) after labeling connected components

![Fig. 11. (a) candidate region and (b) after labeling connected components](image)

Fig. 12. Character segmentation

I. Feature Extraction

Selecting good features is a critical phase in any object recognition system. Here the segmented binary image characters are resized to 50×50. In this phase, we employed a Gabor filter in order to obtain a feature vector. Gabor filtering
is successfully used in many image processing and analysis domains such as: image smoothing, shape analysis, texture analysis, face recognition, fingerprint recognition and iris recognition. The Gabor filter is a band-pass filter whose impulse response is defined by a harmonic function multiplied by a Gaussian function. Thus, a bi-dimensional Gabor filter constitutes a complex sinusoidal plane of particular frequency and orientation modulated by a Gaussian envelope [13]. The most significant advantage of Gabor filters is their invariance to illumination, rotation, scaling, and translation. Here to overcome the problem of slant or skewness, Gabor filter is used.

In the spatial domain, a two-dimensional Gabor filter [14], defined as:

\[ G(x, y) = \frac{f^2}{\pi \sigma^4} \exp \left( -\frac{x^2+y^2}{2\sigma^2} \right) \exp \left( j2\pi f x \phi \right) \]  

\[ x' = x \cos \theta + y \sin \theta \]  

\[ y' = -x \sin \theta + y \cos \theta \]  

Where, \( f \) is the frequency of the sinusoidal factor, \( \sigma \) is the standard deviation of the Gaussian envelope, \( \phi \) is the phase offset, \( \theta \) represents the orientation of the normal to the parallel stripes of a Gabor function and \( y \) is the spatial aspect ratio which specifies the ellipticity of the support of the Gabor function. Our proposed system employs thirty-two Gabor filters in four scales and eight orientations. Then downsampling is done, here column downsampling factors is (5×5). Thus the size of the feature vector obtained is (50×50×4×8) which is 3200. Even after downsampling the feature vector contain using Gabor filter is still large. Therefore, dimensionality reduction methods have been employed. For dimensionality reduction Kernel PCA (KPCA) has been employed. KPCA is a nonlinear dimensionality technique. Kernel PCA is an extension of PCA.

The training and classification processes are done by using Support Vector Machine (SVM) classifier. SVM [19] is a classification prediction tool that uses machine learning concept to maximize predictive correctness while spontaneously avoiding over-fit to the data.

The centering process corresponds to deducting the mean of the features in conventional PCA. It makes guaranteed that the features in the high-dimensional space defined by the kernel function are zero-mean. Then, the principal \( d \) eigenvectors \( \alpha_i \) of the centered kernel matrix are calculated. It can be shown that, the eigenvectors of the covariance matrix \( \alpha_i \) are scaled forms of the eigenvectors of the kernel matrix \( \nu_i \).

\[ \alpha_i = \frac{1}{\sqrt{\lambda_i}} \nu_i \]  

In order to get the low-dimensional data representation, the feature is projected onto the eigenvectors of the covariance matrix. The outcome of the projection (i.e., the low-dimensional data representation \( Y \)) is given by,

\[ Y = \left\{ \sum_j \alpha_j \kappa(x_j, x), \sum_j \alpha_j \kappa(x_j, x), ..., \sum_j \alpha_j \kappa(x_j, x) \right\} \]  

where \( \kappa \) is the kernel function, used in the calculation of the kernel matrix. Since Kernel PCA is a kernel-based technique, the mapping done by Kernel PCA vastly depend on the choice of the kernel function \( \kappa \). Probable selections for the kernel function include the linear kernel, the polynomial kernel, and the Gaussian kernel. In our work, we used Gaussian kernel function. The dimension of the feature vector has been reduced to 140 from 3200 using Kernel PCA.

J. Character Recognition

The training and classification processes are done by using Support Vector Machine (SVM) classifier. SVM [19] is a classification prediction tool that uses machine learning concept to maximize predictive correctness while spontaneously avoiding over-fit to the data.
\[ k(x,x_i) = \varphi(x)^T \varphi(x_i) \quad (13) \]

\( \varphi \) is a nonlinear mapping function used to map input data point \( x_i \) into a higher dimensional space. In our proposed framework, the Gaussian radial basis function [7] is used. It is defined by,

\[ k(x,z) = e^{-\gamma ||x-z||^2} \quad (14) \]

In the high dimensional space we consider that, the data can be separated by a linear hyperplane, according to the following equations,

\[
\begin{cases}
 w^T \cdot x_i + b \geq +1, & \text{if } y_i = +1 \\
 w^T \cdot x_i + b \leq -1, & \text{if } y_i = -1
\end{cases} \quad (15)
\]

In our work, we build two big SVM classifiers for numbers and alphabets respectively. Both classifier implements binary tree structure and applies one against rest to build sub-classifiers. Let us consider numeral classifier as an instance, it contains 9 sub-classifiers. Figure 14 shows the numeral classifier. Each layer contains a digit as a leaf node and a sub-classifier except for last layer that contains two digits as a leaf nodes and the root node is a classifier. Each leaf node is a digit and a positive output (\( y_i = +1 \)), on the other hand each sub-classifier is a negative output (\( y_i = -1 \)).

Fig. 14. Binary tree based numeral classifier

IV. RESULT EVALUATION

All experiments were done on dual-core 3.00 GHz with 2 GB RAM under MATLAB environment. In the experiments, we have used more than 1000 images with the size 640 × 480 pixels. The images were taken from different illuminations, diverse angles and complex scenes. Some example images are shown in Fig. 15. The images for training and testing are unrelated. The database is separated into two datasets. The first dataset contains 100 images with total of 900 characters and are used for training the SVM character classifiers. On the other hand, another dataset contains 917 images with total of 8253 characters and are used for testing the performance of the classifiers. Nevertheless, for license plate detection the entire database was used. The license plate detecting rate of success is 93.2%. And the license plate character recognition rate of success is 99.2%. Results of license plate detection for proposed work in different conditions are shown in table I.

<table>
<thead>
<tr>
<th>Condition</th>
<th>No. of Images</th>
<th>Ex. LPs</th>
<th>Success rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different illuminations</td>
<td>305</td>
<td>292</td>
<td>95.7 %</td>
</tr>
<tr>
<td>Diverse angles</td>
<td>206</td>
<td>195</td>
<td>94.6 %</td>
</tr>
<tr>
<td>Complex scenes</td>
<td>106</td>
<td>98</td>
<td>92.4 %</td>
</tr>
<tr>
<td>Various Environments</td>
<td>400</td>
<td>363</td>
<td>90.8 %</td>
</tr>
<tr>
<td>Total</td>
<td>1017</td>
<td>948</td>
<td>93.21 %</td>
</tr>
</tbody>
</table>

Recognition rate (RR) is calculated as

\[ RR = \left( \frac{\text{No. of recognized samples}}{\text{No. of total samples of that sign}} \right) \times 100\% \quad (16) \]

For example, recognition rate of Bangla number ‘১’ (ek) = (91/91) \* 100 = 100%

Recognition rate for all Bangla characters = (8187/8253) \* 100 = 99.2%

In [1], the system can work very satisfactorily for samples that are not too noisy and not over skewed, which is not practical. Our proposed approach solve the problems of [1].
Table II shows the comparison among applied method and other well reported methods for license plate detection, character segmentation and character recognition. The total process success rate for our proposed method is 91.3%. Figure 16 shows the comparison of overall system performance between our proposed method and other related works. So from the table II and figure 16 we can see that, our proposed method outperforms the existing methods for Bangladeshi license plate recognition.

<table>
<thead>
<tr>
<th>Reference</th>
<th>License Plate Detection Accuracy</th>
<th>Character Segmentation Accuracy</th>
<th>Character Recognition Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed Method</td>
<td>93.2 %</td>
<td>98.1 %</td>
<td>99.2 %</td>
</tr>
<tr>
<td>[2]</td>
<td>88.0 %</td>
<td>98.0 %</td>
<td>98.0 %</td>
</tr>
<tr>
<td>[3]</td>
<td>84.8 %</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>[4]</td>
<td>92.1 %</td>
<td>97.5 %</td>
<td>84.2 %</td>
</tr>
<tr>
<td>[7]</td>
<td>97.6 %</td>
<td>90.7 %</td>
<td>97.9 %</td>
</tr>
</tbody>
</table>

Fig. 16. Comparison of overall system performance between our proposed method and other related works

V. CONCLUSION

This paper presents a vehicle license plate recognition method based on support vector machine. Here, first Sobel operator and histogram analysis is used to detect the license plate region. Subsequently, connected component labeling and bounding box method used to segment the characters. Finally, features are extracted from the segmented character and then character is recognized using support vector machine. During the experiment, different illumination conditions, diverse angles and varied distances between vehicle and camera often occurred. In such cases, the result is very effective when the proposed method is used.

REFERENCES


