License Plate Detection and Recognition System based on Morphological Approach and Feed-Forward Neural Network

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Summary
License Plate Recognition (LPR) is a mass superintending system that captures the image of vehicles and recognizes their license number. There has been a little of work done on Bangla license plate detection which is very important for recognizing the Bangla license plate. The plates with different backgrounds make it more complicated to use the existing algorithms. In this paper, we introduce a new algorithm for detecting Bangla license plate. At first, vehicle location is determined. In Bangladesh, Bangla license plates have some of the unique colors like green for the commercial vehicle and white for the personal vehicle. That's why the portions of green and white colors are selected with the matching RGB intensity of the plate. Then contour algorithm and aspect ratio have been used to locate the license plate region. The rows of the license plate contain registration information that are separated using horizontal projection with the appropriate threshold value. After that, the characters and the digits are also separated using vertical projection with the same threshold value. Finally, we recognize the characters and digits with the help of back-propagation feed-forward neural networks. The proposed algorithms have been tested by 180 images taken under different conditions. The success rate of the license plate detection, segmentation, and recognition process is 93.89%, 98.22%, and 92.77%, respectively.

Key words:
Image processing, License plate detection, License plate extraction, Contour algorithm, Segmentation, Recognition

1. Introduction

In the field of computer vision or digital image processing, the detection and recognition of specific objects in an image such as the detection and recognition of the license plate (LP) area in a vehicle image are the most challenging tasks. There are three major steps for license plate recognition system such as license plate detection, segmenting the characters and digits, and classification of this characters and digits.

In Bangladesh, the Bangladesh Road Transport Authority (BRTA) has declared that the contents of the vehicle license plates (VLPs) of all classes must be written in Bangla following the prescribed government format. The high court of this country has also ordered its implementation. It has become crucial to develop an efficient, advanced, and accurate Intelligent Transportation System (ITS) to fulfill this vision.

The VLPR systems are widely used for detecting speedy vehicles on a highway, controlling security in restricted areas, enforcing traffic law, and identifying vehicles in unattended parking zones. The VLPR task is quite challenging due to multiple LP formats, the changes of the viewpoint of the LP, the non-uniform outdoor illuminations, the weather conditions during image acquisition, blurry images, poor lighting and low contrast, an object obscuring the plate such as a tow bar, or dirt on the plate. In addition, a VLPR system should operate in real time to satisfy the needs of the ITS and never fail to detect LPs from the vehicle image.

There are also some other important applications of LPR system, such as recovering stolen cars, an open warrant for arrest, electronic payment systems, identifying cars with catching speeders, determining what vehicles do or do not belongs to a parking garage, etc.

In this paper, we proposed a contour based technique that matches the RGB color intensity and localizes the plate region by using area and aspect ratio of the region. The skewed image must be corrected before extracting the plate region. After that, the rows that contain information in the license plate are separated. The segmentation of Bangla characters and digits is done by using the horizontal and vertical projections. Finally, classification of the extracted characters and digits are completed by back-propagation feed-forward neural networks.

The rest of this paper is organized as follows. Section II briefly provides a summary of similar researches that has been implemented and tested. Section III represents the specific features of Bangladeshi LP. Section IV introduces the plate region detection, tilt correction, segmentation, and recognition procedures. Section V gives the

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experimental result and compares the performance with the well-known methods. Finally, section VI concludes this paper.

2. Related Research

The combination of edge statistics and morphology are used in [1]. The changes in brightness in the plate region are denser than that of any other part of that image. This has been used as a distinguishing property to locate the plate region. Firstly, the local variance and the gradient magnitude of the edges of an image are computed. Mostly, the license plates are located based on the higher magnitude of the variance and the gradient. Prior knowledge of LPs and color collocation has been used to locate the LP in the vehicle image [2]. A technique based on extract candidate regions by finding vertical and horizontal edges from vehicle region had also been proposed and this segmentation method is named as sliding concentric windows. Finally, vehicle license plate is verified and detected by using HSI color model and position histogram, respectively [3].

In [4], HSI color model is proposed to select a threshold value for locating candidate regions and then some geometrical properties of license plate such as aspect ratio, area, and bounding box are used to determine whether the candidate regions contain LP or not. Some spatial measurements such as area, aspect ratio, and orientation are also introduced with binary image processing algorithms in [5] to locate the license plate in an image. These properties are used to locate candidate license plate regions, which are in fact binary objects. Binary objects whose aspect ratio and area do not fall into the respective reasonable ranges are discarded.

Fuzzy logic has also been utilized for detecting license plates. The authors have made some intuitive rules to describe the license plates and given some membership functions for fuzzy sets, e.g., “bright”, “dark”, “bright and dark sequence”, “texture”, and “yellowness” to get the horizontal and vertical plate positions [6].

Since the license plates can appear at many different angles to the camera’s optical axis, each rectangular candidate region is rotated (i.e., correcting tilt) until they are all aligned in the same way before the decomposition of the candidate region. The license plate skew detection and correction are crucial and indispensable components of the character segmentation and automatic recognition of the LP. The least square fitting with perpendicular offsets (LSFPO) is used in [7] where the VLP region is fitted to a straight line to correct the tilt. The license plate extraction has been accomplished using a Sobel filter and morphological operations in [8]. However, in this paper, the authors do not take into account a skew correction philosophy which is very much essential. In [9], an edge analysis method is applied for number plate detection. Using horizontal and vertical projection analysis, the number plates are segmented into individual words and characters. After that, a robust feature extraction method is employed to extract the information from each Bangla word and character, which is non-sensitive to the rotation, scaling or size variations.

In [10], a method for multi-style LP recognition is presented which introduces a density-based region growing algorithm that accomplishes several things. It performs the LP location detection, the skew refinement, the multi-line LP separation, the optimized character segmentation, and then runs a trainable character recognition method for character recognition. In [11], an image segmentation technique called Sliding Concentric Windows (SCW) has been proposed for detecting a candidate LP region. The main theme of this technique can be viewed as irregularities in the texture of the vehicle image, and therefore abrupt changes in the local characteristics of the image manifest as the presence of an LP. In [12], a method that selects automatically threshold value in HSI color model has been proposed for detecting candidate regions in Korean LP. These candidate regions may include LP regions; geometrical properties of LP are then used for recognizing the characters. Finally, extracting candidate plate region using position in the histogram is done to verify and detect VLP region. Hough Transformation (HT) is also used in [13] to detect the boundary lines of the license plates. The HT is a structure extraction technique that is used to find imperfect instances of objects within a certain class of shapes.

The Sliding Concentric Windows (SCW) based method is proposed in [14] that connect a component analysis (CCA) technique for labelling the pixels. Then the labelled components are examined and the detected license plate is processed to isolate characters. In [15], an adaptive technique with labelling and filtering capability is used to select the required threshold value from automatic threshold and the HSI color model shows the detection of number plate region. Hidden Markov chain [16] is used to model a probable relation between an input image and the corresponding character segmentation.

After least square based skew correction, morphological operations based on pixel connectivity and a character matching algorithm are used to separate and recognize the LP characters [17]. Multilayer feed-forward neural networks have been proposed in many research works to recognize the characters and digits. The network has to be trained for many training cycles to achieve better recognition rate over unknown test data [9, 18].

3. Specific Features of Bangladeshi VLP

In this section, the color arrangement and outline of the Bangladeshi VLPs are discussed. In Bangladesh, a particular type of vehicle has a license plate of a particular style and size. Each style has different background and character colors. The contour of an LP is a rectangle in which the length-to-width ratio is also as per regulations (1.6 - 2.15). In this study, we consider (i) the license plates of private automobiles having a white background and black characters, (ii) the license plates of commercial vehicles having a green background and black characters. Fig. 1 shows a few license plates of those styles.

Fig. 1 Outline of the Bangladesh license plates.

As per the regulations of the Government of Bangladesh, the LPs have the following characteristics:

- Each license plate contains two lines of text containing the region name, vehicle type, and serial number.
- The private vehicles have black text on a white background, and commercial vehicles have black text on a green background.
- There is a rectangle-shaped border around the text. The border's color is black.
- The text is written using Bangla alphabets and numbers.

4. License Plate Detection and Recognition Algorithm

4.1 Overview

It is obvious that an effective LPR system is required for classifying Bangladeshi license plates but there is some LPR system that has been developed for this. In this paper, an LPR system for Bangladeshi vehicle license plates is presented. This system contains mainly four stages such as (i) detection, (ii) tilt correction, (iii) segmentation, and (iv) classification as shown in Fig. 2. In the first stage, the vehicle plate position in the input image is located by using color segment and contour algorithm. In the second stage, if the images are skewed, then it has to be corrected. The skewed image is corrected by using some methods such as Geometrical Transformation, Fitting the Straight Line Based on LSFPO, Fitting the Straight Line Based on LSFVO. Then, the extraction of the required license plate is done. In the third stage, the characters and digits are segmented using horizontal and vertical projections. In the final stage, these segmented characters and digits are classified by using back-propagation feed-forward neural networks.

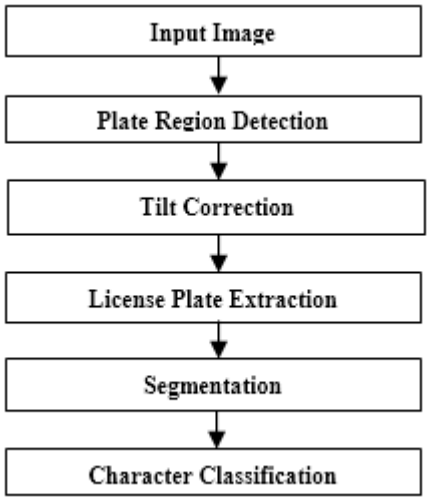


Fig. 2 Overview of the proposed method.

4.2 Plate Region Detection

As stated earlier, the Bangladeshi license plates have some specific features such as green background color for commercial vehicles and white for private vehicles. That's why at first, the portions of white and green colors are selected with the matching RGB intensity of the plate. The RGB value can vary in an image based on the brightening conditions. Since the plate colors are usually defined by the law, so the plate colors are known. The vehicle color is judged by using color samples according to the illumination conditions. The color samples are statistically created which have approximately same color intensity. The color samples may have different illumination conditions which make the plate intensity different.

The vehicle color estimation technique is carried out as the following procedure:

- *Selection of a color sample:* A color sample is created according to the license plate intensity.
- *Judge the color of each pixel in the area:* The nearest color of the pixel from the selected color sample is considered by calculating the RGB color scale.

After taking those selected color area, the image is converted into binary form. Then closing operation is performed to fill the connected regions. A structuring element s is used to do the closing of image f which is

denoted as simply a dilation followed by the erosion. This operation (f.s) is mainly used to eliminate the holes and to fill the gaps in the contour.
The Fig. 3 shows the overall process where,

$$f.s = (f \oplus s)\Theta s \quad (1)$$

and s = structuring element.

Fig. 3 (a) Input image, (b) Binary image (after closing operation).

In order to detect the plate candidate regions, the contour algorithm is used for detecting the closed boundary objects. The next approach is to draw the rectangles over the boundary regions based on their maximum external edge values. These rectangles contain the center, the height and the width of these regions. To locate the plate region, finally the area and the aspect ratio as stated in Table 1 are judged over the selected rectangles. The rectangle that satisfies the area and the aspect ratio is the Region of Interest (ROI).

Table 1: Filtering properties

Filtering Parameter	***Candidate Region (White)***	***Candidate Region (Green)***
Area	[3000, 10000]	[2000, 9000]
Aspect ratio	[1.0, 3.0]	[1.0, 3.0]
Possible shape	Rectangle	

The detected contour and the ROI are shown in Fig. 4(a) and Fig. 4(b).

Fig. 4 (a) Selected contour (marked by pink color), (b) the rectangle over the contour (marked by blue color).

4.3 Skew Correction and Plate Extraction

Before discussing the method used to correct the VLP tilt, first introduce all possible orientation of the tilts that may appear in the VLP region. Based on the direction or orientation, the tilt as it appears in the VLP region can be categorized as horizontal, vertical, and hybrid tilt. The Fig. 5 depicts (a) non-tilted, (b) positively, and (c) negatively tilted LP images where α and θ denotes the horizontal and vertical tilt angle, respectively. Some of the LP images may have only the horizontal or vertical tilt, not both.

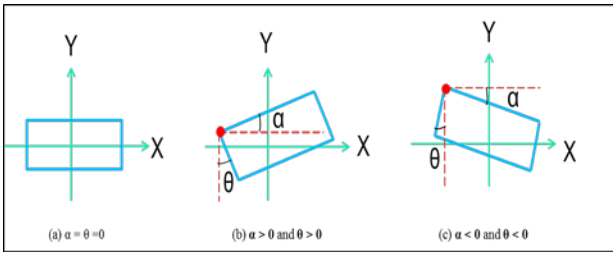


Fig. 5 VLP tilt image (a) no tilt, (b) positive horizontal and vertical tilt, (c) negative horizontal and vertical tilt.

4.3.1 Geometrical Transformation

To correct the skewed image, at first, the rotation angle is detected by using the selectedRect.angle() function. Then, a rotation matrix is multiplied with the image to rotate the image. With the angle, the rotation matrix can be generated. Then the plate region is extracted from the rotated image and is resized to a fixed size for further processing as shown in Fig. 6.

Fig. 6 The extracted (a) white LP, and (b) green LP.

Here, the getRotation matrix is defined by

α β (1-α).center.x-β.center.y
-β α β.center.x+(1-α).center.y

where,

α = scale.cos(angle)
β = scale.sin(angle)

Now, the image is rotated using the rotation matrix where the formula is

dst(x, y) = src(M11x + M12y + M13, M21x + M22y+ M23) (2)

where,

src = input image,
dst = output image,
M = (2×3) rotation matrix.

4.4 Segmentation

The Bangla characters used in Bangladeshi LPs are very difficult to segment because of their various complexities. To overcome these complexities, an algorithm is proposed that uses the horizontal and vertical projections with a threshold value to segment the Bangla characters and digits efficiently. The segmentation process has two steps. In the first step, the separation of the rows is done. Then, segmentation of the characters and digits is done in the second step.

4.4.1 Separating the Rows

The image is converted into grayscale and then Robert cross operator is used for detecting edges. The Bangladeshi plates contain lines of text. The horizontal projection is obtained by the summation of row pixels to detect and segment rows in two different lines. The positions with minimum values of the horizontal projection are the start or the end of a row in the plate. The overall process is show in Fig. 7.

The formula for converting the LP image into the grayscale image is

$$Y = 0.2126R + 0.7152G + 0.0722B \quad (3)$$

Fig. 7 (a) Edge detection, (b) Horizontal projection.

For edge detection, the kernels of the Robert Cross operator are,

+1	0
0	-1

0	+1
-1	0

The gradient magnitude is given by:

$$|G| = \sqrt{(Gx^2 + Gy^2)} \quad (4)$$

Although typically an approximate magnitude is computed using

$$|G| = |Gx| + |Gy| \quad (5)$$

For a given binary image {BI (i, j); 1 ≤ i ≤ H, 1 ≤ j ≤W }, its horizontal projection is computed by using Eq. (6).

$$fh(i) = \sum_{j=1}^{W} BI(i, j) \quad (6)$$

Due to some obstacles like stuck characters, screws, and dash (-) character in the plates, Bangla character segmentation becomes more difficult. That's why before segmenting the characters and digits, the Otsu binarization method is used at each projected rows for better output as shown in Fig. 8.

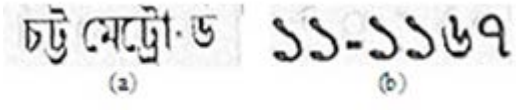


Fig. 8 The segmented rows after the Otsu method.

4.4.2 Segmenting the Characters and Digits

The vertical projection is used for separating the Bangla characters and words. In this vertical projection, the screws

and dash (-) character are removed which have a very small frequency. After applying this process, 9 top picks are found from each number plate where there are 7 characters and 2 words as shown in Fig. 9. Now, we remove the redundant area form each output of the segmentation process.

For a given binary image {BI (i, j); $1 \le i \le H$, $1 \le j \le W$}, its vertical projection is computed by using Eq. (7).

$$fv(i) = \sum_{i=1}^{H} BI(i, j) \tag{7}$$

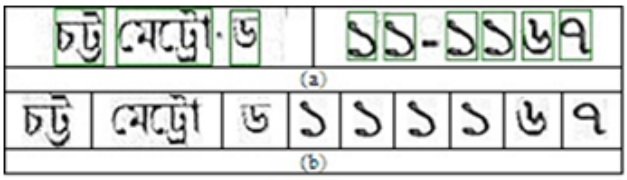


Fig. 9 The segmented (a) rows, and (b) Bangla words and digits.

4.5 Character Classification

As the license plates can appear at many different angles (i.e. tilted) and/or bent with respect to the camera's optical axis, the alphanumeric characters extracted from such license plates may be deformed. In addition, the input characters may be broken or incomplete and noisy. The character recognition methods would be able to permit these defects. So, the back-propagation feed-forward neural networks are used for the recognition of the segmented alphanumeric characters used in Bangladeshi vehicle LP.

The used feed-forward network has three layers namely the input, the hidden, and the output layer. The architecture of the back-propagation feed-forward neural network is described in details in the following sections [19].

The LP character recognition system consists of two major components such as

- Training component,
- Recognizer component

and the major steps involved in this components are shown in Fig. 10 and described in below.

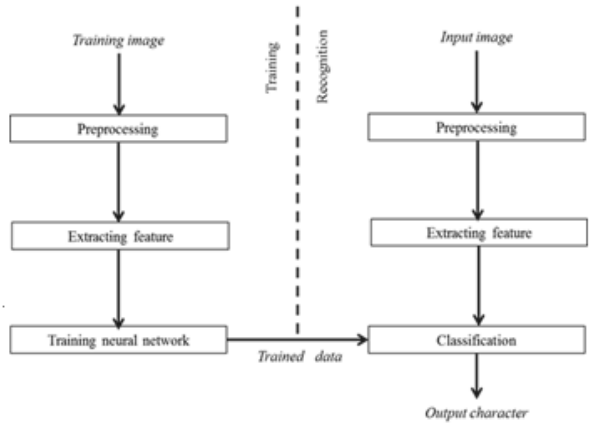


Fig. 10 The training and the recognizer module.

The Training Image: The black and white images consisting of the numbers or characters are used to train the classifiers.

Pre-processing: The training and the input images should make noise free to the some extents. The training image is then segmented and the user is asked to label the images to create the training examples.

Feature Extraction Module: This module extracts the features from the training examples or the input image.

Neural Network Module: The segmented character images are resized to 12×9 pixels and then given as the input to the neural networks which are trained using the back-propagation algorithm.

Classification: It can be seen from the figure that the classifier performs the recognition using the trained data from the neural network and the pre-processed input image, and finally shows the recognized character as the output.

4.5.1 Training Component

This component is responsible for creating and training the neural network. To train the neural network developed for recognizing the Bangla numbers in the license plate, a training image file consisting of a few sample images of each of the Bangla numbers

০, ১, ২, ৩, ৪, ৫, ৬, ৭, ৮, ৯

is used. Another training image file containing a few sample images of each of the Bangla words/characters used in the license plate such as

চট্ট, ঢাকা, মেট্রো, ক, খ, গ, ঘ, চ, জ, ম

is used to train another neural network developed for recognizing this words/characters. After training both the neural networks, the training data are saved into a separate file.

The major steps to create and train the neural network are presented in the following algorithms:

Algorithm 1: To create and train the neural network.

i) Load the training image file.
ii) Convert the loaded training image into binary image and labelling it.
iii) Segment the training labelled image file into constituent numbers or characters using connected component analysis.
iv) Assign a class (e.g., 1 for চট্ট, 2 for মেট্রো, 3 for ঢাকা,……., etc.) to each category of the number or character image.
v) Resize the extracted segment image into 12×9 size.
vi) Create the neural network and train it using the resized training samples.
vii) Save the training data.

4.5.2 Recognizer Component

This component is responsible for the recognition of the words/characters. Before providing to the recognition scheme, the characters are normalized. Normalization is to refine the characters into a block containing no extra white spaces i.e., pixels on all the four sides of the characters. Then each character is fit into 12×9 size. The major steps are presented in the following algorithms:

Algorithm 2: To simulate the character of the neural network and calculate the output of the network.

- Load the saved training data.
- Invert and pre-process the character image to be recognized.
- Resize the character image into 12×9 size.
- Simulate this character on the developed neural network using loaded training data.
- Calculate the output of the network and return the result.

Algorithm 3: To recognize an LP character.

i) Read the LP character to be recognized.
ii) Convert the character into the binary image.
iii) Call the procedure of [Algorithm 2].
iv) Return the result.

An example of the result of the recognition process for the given alphanumeric characters is shown in Fig. 11.

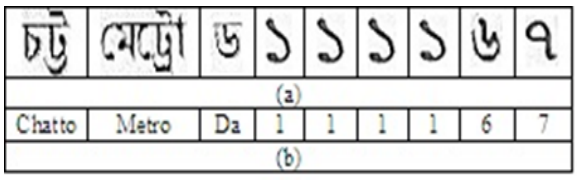


Fig. 11 Illustration of the alphanumeric characters recognition (a) candidate alphanumeric characters for recognition, (b) recognized alphanumeric characters.

5. Experimental Results

All of the experiments have been done on an Intel(R) Core(TM) i5-3230M CPU, 2.60 GHz with 4 GB RAM under a MATLAB development environment. In the experiments, we have used 180 images with the size of 640×480 pixels. The images are captured from 2 to 7 meters distance between the camera and the vehicle. We use zoom in/out and imaging size parameters of the digital camera. The Fig. 12 shows some example images taken under different illuminations (strong sunshine, night, shadow, cloudy, etc.), when the vehicle and LP have similar colors, with complex scenes (having objects such as hands, human beings, and light posts in front of vehicles). It also shows some simple vehicle images.

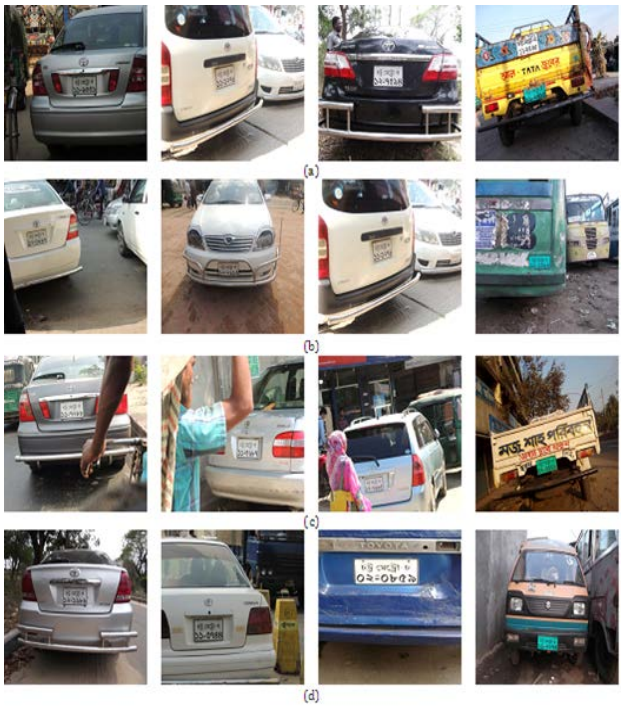


Fig. 12 The example images (a) non-uniform outdoor illuminations, (b) similar color of vehicle bodies and LPs, (c) complex scenes, and (d) simple vehicle images.

5.1 Evaluation of LP Detection Process

Considering the above conditions, the successful LP detection rate is about 93.89%. The Table 2 shows the experimental result of the system.

Table 2: Detection results

Image Groups	*Total Images*	*Extracted LPs*	*Success Rate (%)*
Complex scenes	27	24	88.89
Different illuminations	22	20	90.91
Similar vehicle and LP color	47	44	93.62
Others	84	81	96.43
Total	**180**	**169**	**93.89**

5.2 Evaluation of Tilt Correction Process

Using the proposed method of tilt correction, the tilt angles are calculated considering both the lower and upper horizontal axis (for horizontal tilt), and the left and right vertical axis (for vertical tilt) and select the maximum one in each case. This proposed LP tilt correction framework is compared with the method (fitting the straight line based on LSFPO) of [11]. In comparison, it is found that the proposed method works well.

5.3 Evaluation of Recognition Process

The objectives of the recognition process are to recognize the alphanumeric characters both Bangla numbers and words/characters written in the license plate. The developed recognition process based on the back-propagation feed-forward neural network met the objectives. Under testing circumstances, the execution time and the accuracy rate of recognizing Bangla alphanumeric characters are found quite satisfactory.
The performance metrics of the developed neural network and the average computational time for the recognition of single number or word/character are shown in Table 3 and Table 4, respectively.

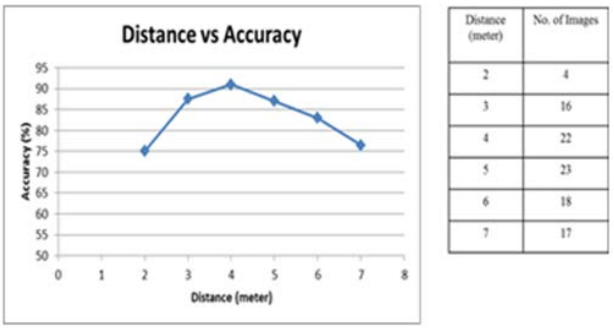
Table 3: Performance metrics of the neural network

Metrics	*Formula*	*Value*
Accuracy	(True positives + True negatives)/ Total population	0.970
Precision	True positives/(True positives + False positives)	0.987
Recall	True positives/(True positives + False negatives)	0.981

Table 4: Average computational time for single character recognition

Type	*Average computational time (s)*
Number	0.0238
word/character	0.1035

The distance versus accuracy curve for the recognition system considering 100 input images is shown in Fig. 13. The accuracy rate is minimum (75%) and maximum (90.5%) when the distance between vehicle and camera is 2 and 4 meters, respectively.



Distance (meter)	No. of Images
2	4
3	16
4	22
5	23
6	18
7	17

Fig. 13 Distance vs accuracy curve.

The summary of the accuracy of LP extraction, tilt correction, segmentation and character recognition process is given in Table 5.

Table 5: Summary of accuracy

Process Name	*No. of Inputs Images*	*No. of Successful Outputs*	*Success Rate (%)*
LP Extraction	180	169	93.89
LP Tilt Correction and Segmentation	169	166	98.22
LP Character Recognition	166	154	92.77
Total	180	154	85.56

As no research result is available for the newly introduced format of the Bangladeshi license plates, this test results are compared in terms of accuracy with the methods of [8] and [9] where the inputs are old format LP. The comparison results are shown in Table 6.

Table 6: Comparison results

Method	*Success Rate*
[8] (Old format LP)	67.20%
[9] (Old format LP)	75.51%
The Proposed Method (New format LP)	85.56%

These results show that the proposed method exhibits better performance compared to the previous methods and 85.56% accuracy that is impressive as well as promising for future implementation.

6. Conclusion

In this paper, we present a set of algorithms for the detection, segmentation, and recognition of license plates written in Bangla. In each stage, the developed techniques and algorithms are suitable for recognizing Bangladeshi license plates. The license plates are detected in the vehicle images by using the property of color and contour. The result of the proposed method is very effective for different viewpoints, illumination conditions, and varied small

distances between the vehicle and camera. Our algorithm are tested by 180 input images and found that the proposed scheme outperforms the existing algorithms in the recognition of the Bangladeshi license plates.

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