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Bangla License Plate Detection, Recognition and Authentication with Morphological Process and Template Matching

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***Abstract*—In Bangladesh, Bangla license plates are Retro Reflective having two lines with alphabets, words and digits. In this paper a method is proposed to detect, extract, recognize and authenticate Bangla license plates. The proposed method consists of four modules named preprocessing and processing of the license plates, recognize the characters of the plates and authenticate whether the vehicle is registered or not. Different processes like edge detection using sobel operator, a series of morphological operations, character segmentation using connected component analysis, character recognition using template matching technique are used in the proposed method. Authenticating the vehicle is a unique feature of the proposed method. A database of 250 car license plate images in various environmental conditions is prepared for this project. We have also prepared another two databases of templates for recognition and of registered cars for authentication purpose. The proposed method has achieved an accuracy of 94% in detection, 96.1% in character recognition and 100% in authentication of vehicle number plates.**

Keywords—bangla number plate, edge detection, character recognition, authentication, morphological operation, connected component analysis, template matching

I. INTRODUCTION

Due to the faster growth of Bangladesh's population, the number and the use of vehicles has increased significantly in recent years. Significant incidents were caused by acts such as auto theft, failure to observe traffic rules, reckless driving, and excessive overtaking. Because of the high density of vehicles on the road and the rise in vehicle-related crime, the need for vehicle number plate detection is growing. It aids in the detection of criminally responsible vehicles. It can also be used in various parking lots to keep track of cars and in toll booths to collect tolls. Automatic Number Plate Recognition (ANPR) is a system that detects a vehicle's number plate and uses that information to classify it. A vehicle's number plate is its specific identification. In Bangladesh, the number plate detection process is still performed manually. If we can automate this manual operation, it will play a critical role in Bangladesh's traffic surveillance system. In the field of automatic number plate detection and recognition, several research studies have been carried out in other countries; however, Bangladeshi number plate detection has received relatively little attention.

In [1], the authors suggest a recognition technique for automated BD vehicle number plate recognition. This process is extremely successful at removing license plates from captured images. This method employs the sobel edge detector, which is convolved with the target image. The estimate of derivatives for horizontal and vertical changes is calculated using this method. The threshold value is determined using the combined mean and variance. The model then generates an image matrix that can be traversed to find the maximum feature points of a rectangular shape region. If the rectangular form has a maximum value, it will be cropped. By combining the edge analysis method with mathematical morphology, reference [2] provides strong edge details. The sobel operator is also used in this case. For identification, they used a template matching technique based on the minimum Euclidean distance. Within 0.3 seconds, 90% of the images are correctly read. The intensity values within the plate region are determined using a morphological operation and a Gaussian function. The researchers of [3] presented a process that can accurately detect and recognize license plates. This approach works with Arabic letters and Hindi numbers and provides an accuracy of 80%. In [4], authors suggest an improved Bernsen algorithm for finding the license plate. This algorithm is effective in situations where there is unequal lighting or removing shadows. To boost the accuracy, various techniques such as local Otsu, global Otsu, and differential local threshold binary methods are used. In their paper [5], S. Rasheed, A. Naeem, and O. Ishaq present a novel technique for detecting and identifying Islamabad vehicle plates. It consists of two modules: a license plate location module and a license plate recognition module. The license plate location module employs a canny detector and Hough lines, while the identification module employs template matching.

One of the first challenges we encountered while working in this research was the lack of a publicly accessible dataset for Bangla license plates. In addition, unlike the most popular one-line license plate format around the world, Bangla license plates have two lines [6]. Another challenge that we faced is that car owners were reluctant to provide us permission to take pictures of their car license plates. That's why it took long time to prepare a database of 250 Bangla license plate images. There are normal, bright, dark, distant, blur, skewed, tilted, & noisy images in our database. We have also prepared Bangla templates (alphabetic, numeric and word) for the recognition purpose. Pre-processing, processing, recognition and authentication of the license plate image are the four key components of the proposed system. The captured image is read, resized, and converted to gray-scale during pre-processing. Then, in the processing

part, the plate location is extracted, followed by a segmentation process to separate the characters of the plate. Plate characters are recognized using correlation-based template matching. The license plate number saved in a text file is matched with a database prepared for the authentication purpose of the vehicles.

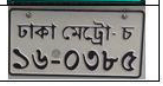
Vehicle Category	License Plate Colour	Character Colour	License Plates
Commercial	Green	Black	
Private	White	Black	

Fig. 1. Bangladeshi vehicle number plate categories

Fig. 2. Bangladeshi vehicle number plate sample

II. Properties of License Plates of Bangladesh

The Bangladesh Road Transport Authority (BRTA) is the only authority in Bangladesh that can issue different types of vehicle license plates. The original edition of BRTA license plates was introduced in 1973, but digitization of these plates began in 2012 [6]. The use of digital license plates on both the front and rear sides of a vehicle is now required, with the rear license plate being permanently attached. The commercial car license plate colour is green whereas non-commercial car license plate colour is white. The categories are depicted in Fig.1.

The registration number of license plates in metropolitan cities must be written in Bangla script on a flat steel or aluminum plate with dimensions of 524mm x 112mm for a vehicle, according to BRTA regulations [7]. The plates must also conform to a particular color code depending on the vehicle type; however, the algorithm proposed here is unaffected by these colour patterns. The different words and characters follow a uniform pattern that is shown in Fig.2.

The upper line consists of Bangla words & alphabets and the lower line consists of Bangla numbers. The first Bangla word of the upper line denotes the city area name to where the car is registered. The second word denotes "Metro" which is a short form of metropolitan. The third one is a Bangla alphabet denotes the vehicle class means whether it is a truck, motorcycle, private car etc. The lower line consists of six digits where the first two indicates the vehicle class number and the next four denotes the unique identification number of that vehicle.

There is an important feature of Bangla language known as Matra [7]; a horizontal line situated in the upper part of maximum Bangla alphabets. We can count two or more Bangla characters as a word if they are connected with a continuous matra. In Fig.1, the two words that are connected through a matra are city name and metro.

III. Proposed Method

Fig.3 and Fig.4 depict the block diagram and flowchart of the proposed method. It has four major stages: pre-processing and processing of the acquired image, recognition of characters from that image and authentication of the car.

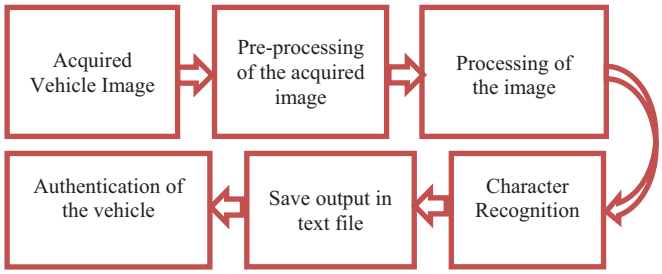


Fig. 3. Block diagram of the proposed method

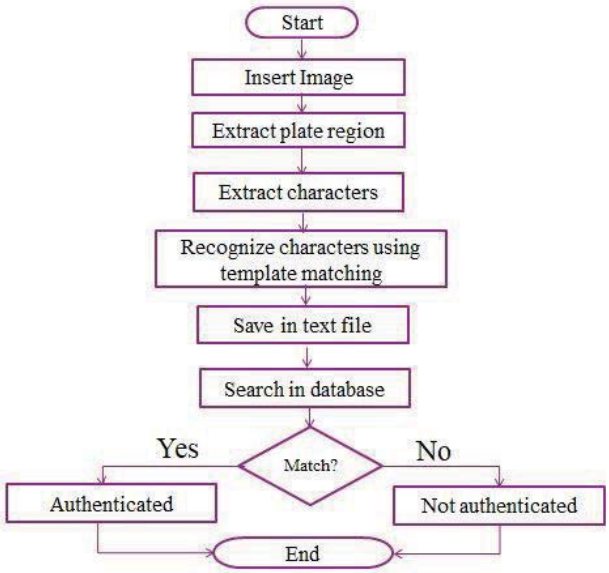


Fig. 4. Flowchart of the proposed method

Fig. 5. Read image

Fig. 6. Gray-scale image

A. Pre-processing of the acquired image

1) Read image: This is the very first stage of our proposed method. Car image is captured and read by MATLAB software in this stage. Fig.5 depicts the read image or test image.

2) Resize Image: As the captured image can be of any size, we need to resize it to a predefined size. In this proposed method the height of the car image is converted into 400 pixels whereas aspect ratio is unchanged.

3) Convertion from RGB to gray-scale image: The processing of a RGB image is complex and time consuming. That's why the resized image is converted into a gray-scale image shown in Fig.6. At first the red, green and blue components are splitted and converted into gray image using (1).

$$Gray\ Image = 0.2989 * R + 0.5870 * G + 0.1140 * B \quad (1)$$

4) Binarization of gray-scale image: The gray image is then converted into binary image (Fig.7) by Otsu method [8]. This method first calculate a threshold value by (2) and then starts the conversion process.

$$g(x,y) = \begin{cases} 1; if\ xy \geq T \\ 0; otherwise \end{cases} \quad (2)$$

Fig. 7. Binarized image

Fig. 8. Detected edge of license plate

B. Processing of the image

1) Edge Detection: The detection of edges is an important step in object recognition. It's an approach for identifying sharp discontinuities in images. Discontinuities are the sharp changes in pixel density that define the edges of objects in a scene. In a nutshell, edge detection's aim is to establish a line drawing of the input image. Sobel operator is used to detect the edges so that we could define the license plate area shown in Fig.8. It is called a discrete differential operator. It uses two 3x3 kernels: Equation (3) estimates the vertical componets of the gradients, while (4) estimates the horizontal components of the gradients [9].

$$G_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} \quad (3)$$

$$G_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad (4)$$

2) License Plate Area Detection: In this stage regionprops command of MATLAB is used to detect the area of license plate. To complete the process of license plate area detection some morphological operations are done.

a) Image Dilation: The edge lines are expanded at this stage which are already detected in edge detection step by using the process using in [10]. We got a thicker edge line than the previous stage shown in Fig.9.

b) Image Filling: The license plate area (edges are already detected by sobel operator) is filled-up with white pixels as shown in Fig.10. The black areas inside the edges are replaced with white pixels [10].

c) Image Eroding: Eroding is a technique for erasing or dissipating a small area of white pixel from an image [11]. This stage is used to remove the extra edge line from the vehicle picture as in Fig.11.

Fig.9. Dilated image

Fig.10. Filled image

Fig. 11. Eroded image

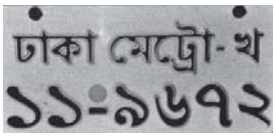


Fig.12. Extracted image

Fig.13. Finding area of each character

Fig.14. Segmented characters

3) Extracing License Plate Region: License plate region extraction is one of the important phases of the proposed method.

a) Image Multiplication: At this stage the eroded image is multiplied with the gray scale image providing us an output with only the license plate region.

b) Plate Extraction: The license plate is then extracted from the multiplied image by using regionprops command in MATLAB. By this method, sudden change of pixel values from zero to high is detected, marked and smallest possible rectangle is found out [12]. This rectangle is the exact license plate area shown in Fig.12.

c) Character Segmentation: Two lines of characters appear on a Bangladeshi license plate. One or two Bangla words and one Bangla letter form the first line. According to the BRTA's Retro- Reflective standard, the second line has six digits [7]. Each of the six digits is isolated from the others. However, “Matra” is used to link the alphabets that make up a word (a line connects multiple characters). The entire word "Matra" is considered to be a single connected component.

For segmenting the characters, connected component analysis is used here. The extracted license plate image is binarized first and then boundary boxes colored green are formed for each one of the connected objects in the image shown in Fig.13. After that, the unwanted boxes are removed by setting up a threshold value of 20 pixels for both the heights and widths. The characters are then extracted from the plate and saved as a distinct image. The characters and words that has just been segmented are sent to the recognition module. The segmentation process is done using the techniques used in [13].

C. Recognition of the characters

At this stage the characters should be recognized that are already segmented and saved as a distinct image. In the proposed method template matching technique is used. All the template images are of 100 pixels in height and 65 pixels in width. A general module for character recognition is created and the properties of the captured and resized images are sent to recognition module. Each saved character image is correlated with every template to find the best

possible match [7]. Equation (5) is used to find out the 2D correlation coefficient "r" that detects the best possible match.

$$r = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{(\sum_m \sum_n (A_{mn} - \bar{A})^2)(\sum_m \sum_n (B_{mn} - \bar{B})^2)}} \quad (5)$$

Here, $\bar{A}$ and $\bar{B}$denotes the average of the image matrices $A_{mn}$and B_{mn}respectively.

The characters are saved as a string after all of them have been successfully recognized. The final output shown in Fig. 15 is generated into a single text file named as "License_Plate".

D. Authentication of the vehicle

In the proposed method, the authentication of the vehicle is done. Our goal is to match the vehicle's plate number to the database. We had a predefined database of 250 registered vehicle license plate numbers mentioned in section IV. The information in this database is stored in a text file. Then we matched the database text file with the text file containing the testing vehicle number using the "strfind" command in MATLAB [14]. If it is a match the output will be like in Fig.16 and if it is not a match the system will detect the car as an illegal one as shown in Fig.17.

IV. DATABASES

For this project we have prepared three databases. These datasets are created for the smooth running of the project. The datasets are testing image database, the template database and car license plate database.

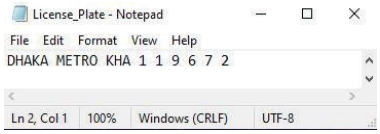


Fig. 15. Final Output as text file

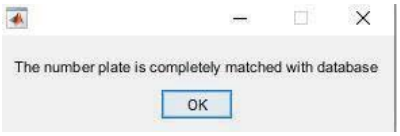


Fig. 16. Output if car is registered

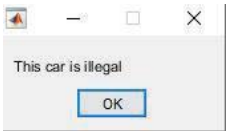


Fig. 17. Output if car is not registered

Fig. 18. Templates

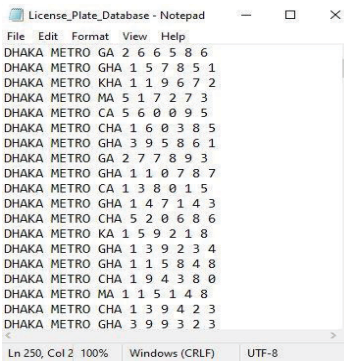


Fig.19. License Plate Database

1) Testing Image Database: In testing image database, captured car images are stored in JPEG format, having of any size. Images are taken at various environments, luminance and positions. So, finally we have got the testing set of 250 car license plate images considering of normal, distant, bright, dark, blur, skewed, tilted and noisy images.

2) Template Database: We have created a database of templates for recognizing the characters. Those templates are made with a special font so that all of the characters on a license plate can be recognized. These models are saved in BMP format and are 100 pixels in height and 65 pixels in width. There are numeric, alphabetic and word characters in the template database. Fig.18 shows some of the character templates used in this project.

3) License Plate Database: For checking the authentication of the car license plate whether it is registered or not we have created a database of 250 car license plate numbers in a text file shown in Fig.19.

V. EXPERIMENTAL RESULTS & DISCUSSION

Experimental setup, findings, analysis, and discussion of the results, as well as the results found in previous studies, will be covered in this section.

1) Experimental Setup: MATLAB 2018a is used in a laptop having configuration of Intel core i5 with 8 GB RAM and GTX 1050 Ti (4GB) GPU. Images are captured manually by a 20 MP mobile camera. The characteristics of the acquired/captured images are shown in Table I.

2) Results: The extraction, recognition and authentication of license plates of some of the test images in different environmental conditions are shown in Table II. It can be understood that this proposed model is capable of extracting car license plate numbers from illuminous, dark, blur, distant & noisy, tilted and skewed images. The maximum distance of the captured image should be 1m and the proposed model can extract & recognize the number plates having tilted or skewed of maximum 10 degrees. Both commercial and private vehicle number plates mentioned in section II can be detected & extracted by this method. Table III represents the success rate of the proposed method in different stages. 235 license plate images are detected out of 250 providing us an accuracy of 94% in detection. The recognition accuracy is 96.1%. The proposed method can authenticate each of the number plates that pass the detection and recognition stages. The overall accuracy of the proposed method is 96.7%.

TABLE I. CHARACTERISTICS OF CAPTURED NUMBER PLATES

Type of the number plate	Double line
Shape of the number plate	Rectangular
Background of the number plate	White, Green
View	Front, Rear
Distance	Maximum 1m
Tilted/Skewed	Maximum 10 degrees

TABLE II. EXTRACTION, RECOGNITION AND AUTHENTICATION OF NUMBER PLATES OF SOME TEST IMAGES

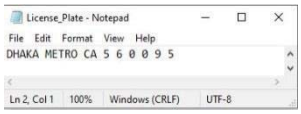
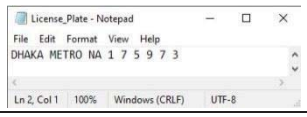
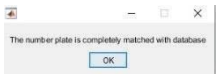
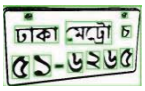
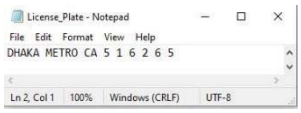
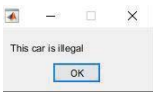
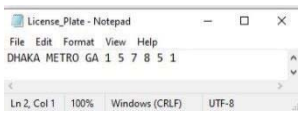
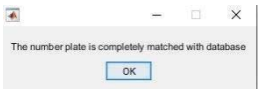
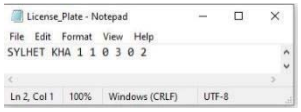
Test Image	Environment	Extracted Number Plate with boundary box	Recognition	Authentication
	Bright			
	Distant & Noisy			
	Skewed			
	Tilted			
	Blur			

TABLE III. SUCCESS RATE OF OUR PROPOSED METHOD IN DIFFERENT STAGES

Stages	Success Rate	No. of License Plates	
		Passed	*Total*
Number Plate Detection	94%	235	250
Character Recognition	96.1%	226	235
Number Plate Authentication	100%	221	221
Overall Accuracy	96.7%	N/A	

3) Comparison with other methods: Table IV depicts the accuracy comparison of the proposed method with recent works in this field. To complete the whole process the proposed model need only 0.2 seconds less than the models proposed in [15] and [17].

TABLE IV. ACCURACY COMPARISON WITH OTHER METHODS

	Accuracy Rate (%)				Total processing time
	D	*R*	*A*	*O*	
Proposed Method	94	96.1	100	96.7	0.2 sec
[13]	93.78	97.03	--	95.41	--
[15]	86.2	95	--	90.6	0.47 sec
[16]	94	95.74	--	94.87	0.18 sec
[17]	Not given	85	--	85	0.75 sec

[a] **D**: Detection, **R**: Recognition, **A**: Authentication, **O**: Overall

The detection, recognition and overall accuracy of the proposed model are higher than the other methods mentioned in Table IV. None of the proposed methods in Table IV other than ours can authenticate the vehicle number plates to know whether it is registered or not. This is a unique feature of our proposed method.

VI. CONCLUSION

In the proposed method, an effective and fast algorithm is developed and implemented to detect, extract, recognize and authenticate Bangla license plates. This method includes preprocessing of the captured image followed by edge detection, a series of morphological operations, character segmentation using connected component analysis, character recognition using template matching technique and authentication of the vehicle. Authenticating the vehicle is a unique feature of the proposed method. The overall accuracy and processing time is better than some of the recent works done in this field. We have worked with an image dataset of 250 images of both commercial and private vehicles in different environmental situations. We will work on real time system in future. Neural network and SVM techniques can be used for recognizing characters as template matching faces some problems while detecting ambiguous characters that are look alike.

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