An Innovative Approach for Bangladeshi Vehicle Number Plate Recognition, Authentication and Verification

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1 Introduction

In this study, we propose an automated approach for the detection, recognition, and validation of Bangladeshi number plates. In a densely populated country like Bangladesh, where the rapid increase in the number of vehicles has led to various challenges in traffic management and revenue collection. The current manual processes for verifying vehicle registration and tax token status are time-consuming and prone to errors. Besides, as many car-owners do not renew the tax token of their registered car after the expiry date, the government of Bangladesh loses a handsome amount of taxes each year (BRTA, 2019). To address these challenges, the research proposes to develop an automated system for the detection, recognition, and verification of Bangladeshi vehicle number plates based on advanced techniques such as morphological image processing and template matching. The proposed system consists of four several stages - preprocessing, extraction, segmentation, recognition, and verification of number plates.

1.1 Details about Bangladeshi number plates

Bangladeshi vehicle number plates, there are two lines. The first line contains information about the city where the car is registered. It might also include the vehicle's category, like whether it's a private car, motorcycle, or truck. The second line is the vehicle's unique serial number. [See in Fig. 1(a) and 1(b)]

The letters allowed for use on Bangladeshi number plates, along with their English equivalents, are listed as follows: অ (A), ই (I), উ (U), এ (E), ক (KA), খ (KHA), গ (GA), ঘ (GHA), ঙ (UMA), চ (CA), ছ (CHA), জ (JA), ঝ (JHA), ট (TA), ঠ (THA), দ (DA), ধ (DHA), ত (TO), থ (THO), ড (DO), ঢ (DHO), ন (NA), প (PA), ফ (FA), ব (BA), ভ (BHA), ম (MA), য (ZA), র (RA), ল (LA), শ (SHA), স (SA), and হ (HA). The allowed numerical digits are ০, ১, ২, ৩, ৪, ৫, ৬, ৭, ৮, ৯, which are equivalent to 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 in English.

The color of the number plates can vary. Green background plates are used for commercial vehicles, while white background plates are for private vehicles. Both types of plates have a black border.In the Bangla language, there's a unique feature called 'matra.' It's a horizontal line that connects certain Bangla letters at the top. When letters are connected by a 'matra,' they are considered as a single word.

1.2 Related Works

Mashuk et al. (2010) proposed an automatic method for detecting and recognizing Bangladeshi analog number plates and their characters using the Sobel operator, morphological operations, and Backpropagation Neural Network (BPNN). Roy et al. (2016) developed an automatic system for license plate detection and character recognition of Bangladeshi commercial vehicles using a boundary-based contour algorithm and template matching. Uddin et al. (2016) presented an automatic process

(a)

Vehicle Category	License Plate Colour	Character Colour	License Plates
Commercial	Green	Black	ঢাকা মেট্রো- ন ১৭-৫৩১৩
Private	White	Black	ঢাকা মেট্রো- ক ০৩-৬৪০৬

(b)

Figure 1: (a) Sample of number plate for Bangladeshi vehicle, (b) Categories of vehicle

for Bangladeshi digital number plate detection, segmentation, and character recognition using the Sobel operator, histogram analysis, and Support Vector Machine (SVM). Chandra et al. (2017) introduced a four-step method for recognizing Bangladeshi license plates using the Sobel operator, bounding box techniques, Radon, and Affine transformation. Hossain et al. (2018) proposed a morphological operation and template matching-based technique for Bangladeshi license plate area localization and character recognition. Rabbani et al. (2018) presented an automatic technique based on morphological operation and CNN for localizing license plates and recognizing Bangla characters.

1.3 Limitations of Previous Works

In the field of automatic number plate recognition, previous studies have primarily focused on detecting and recognizing Bangladeshi number plates. These approaches have included techniques such as edge detection, morphological operations, and template matching. However, none of these existing systems have addressed the critical issue of verifying vehicle registration and tax token status. Till now, no research has been done on the number plate authentication and verification process. Besides, there is a scarcity of datasets of Bangladeshi number plate images. Moreover, there is no enriched dataset and cloud database containing vehicle details.

1.4 Scope of Future Work

To address this gap, we plan to create a specialized dataset with a higher number of sample images of digital number plates in the future, which will enable us to conduct character recognition and vehicle verification. We are planning to prepare three types of datasets - testing image dataset, template dataset (for character recognition purposes), cloud dataset containing the car details (for authentication and verification purposes) and to make a system that will outperform the existing methods in terms of achieving accuracy in detection, extraction, segmentation and recognition and add verification system as a distinctive feature of this current study. BRTA has introduced the retro-reflective Bangla digital license plates in 2012. They have made it mandatory to use digital number plates in vehicles since 2016 (Saif et al., 2019). For this reason, we will consider digital number plates only in our research.

2 Literature review

Mashuk et al. (2010) present an automated approach to detect, extract, and identify Bangladeshi analog number plates and their characters. They utilize the Sobel operator to identify plate edges and employ morphological operations alongside the bounding box technique for plate localization and character segmentation. Amin et al. (2014) introduce an automatic method for recognizing Bangladeshi analog number plates. They employ the Sobel edge detector to locate plate edges, and then use Hough transformation and Optical Character Recognition (OCR) to localize plates and recognize the characters. Their dataset comprises 80 Bangladeshi number plate images, yielding accuracy rates of 88% for plate region localization, 77% for plate area extraction, and 62% for character recognition. The main reason for this recognition problem is because of the variation of the fonts, especially for handwritten fonts used in our Bangladeshi vehicles. Roy et al. (2016) present an automated technique for detecting and recognizing license plates on Bangladeshi commercial vehicles. They utilize a boundary-based contour algorithm and template matching for plate localization and character recognition, respectively. Their dataset consists of 180 images of Bangladeshi car license plates, achieving accuracies of 93% for plate area detection, 98.1% for segmentation, and 88.88% for character recognition. Chandra et al. (2017) propose a four-step approach for recognizing Bangladeshi license plates, encompassing detection, extraction, segmentation, and character recognition. They use the Sobel operator and bounding box techniques for edge detection and plate area extraction, respectively. Radon and Affine transformations are employed for tilt correction. Their dataset includes 400 images of Bangladeshi car license plates. Rabbani et al. (2018) introduce an automatic technique that combines morphological operations and Convolutional Neural Networks (CNN) to localize license plates and recognize Bangla characters. They apply connected component analysis for character segmentation and work with 100 Bangladeshi license plate images, achieving detection, segmentation, and recognition accuracies of 93.78%, 95.45%, and 97.03%, respectively. Islam et al. (2020) propose a morphological image processing and template matching-based approach for localizing number plates and recognizing characters on English number plates. The Sobel operator and bounding box methods are used for edge detection and character segmentation.

In the above literature I found that none of these existing methods has worked for the authentication and verification process of vehicles. In this study, we propose an automated approach for the detection, recognition, and validation of Bangladeshi number plates. Our method will include four essential steps: preprocessing, extraction and segmentation, recognition, and verification of the number plates. We'll use advanced methods like improving image contrast and fixing tilts to make our approach more accurate. The proposed methodology will depend on a combination of advanced techniques including edge detection, morphological operations, the bounding box method, and connected component analysis for the precise extraction and segmentation of number plates and their constituent characters. For character recognition, we will conduct the template matching method. One of the distinguishing features of our approach in comparison with the existing methods will be the authentication and verification process for vehicles. To support our research, we will create a rich dataset containing Bangladeshi number plate images. Additionally, we are planning to develop a comprehensive template dataset and a cloud-based database housing vehicle details for number plate character recognition and vehicle verification purposes. Our proposed methods will outperform many existing methods in this domain. We'll work so that the total processing time taken by the proposed method from the detection stage to the verification stage can be significantly less than the other existing methods.

3 Problem Definition

This research addresses the core problem of the need for an automated system to detect, recognize, and verify Bangladeshi vehicle number plates. Manual verification processes conducted by traffic police are labor-intensive and ineffective, posing a set of specific challenges. Firstly, the reliance on manual verification of vehicle number plates by traffic police is labor-intensive and inefficient. Secondly, the issue of Tax Compliance is a significant concern. Many vehicle owners fail to renew their tax tokens, resulting in substantial revenue losses for the government. Thirdly, the identification of Stolen Vehicles or misused vehicles is challenging using manual methods. Fourthly, The increasing number of vehicles has led to rampant traffic violations, making enforcement difficult. Lastly, the Research Gap in the field of Bangladeshi vehicle number plate Detection and Recognition is evident. Limited research has been conducted on Bangladeshi vehicle number plate detection and recognition, necessitating a specialized approach. By addressing these issues, the proposed system seeks to improve traffic management, enhance tax collection, and contribute to the broader field of ANPR research.

4 Objectives

The primary objective of this research is to develop an automated system for efficient and accurate detection, recognition, and verification of Bangladeshi vehicle number plates, alleviating the burden on traffic police and enhancing traffic management. Secondly, the research seeks to Enhance Accuracy by using advanced image processing techniques. This will significantly improve the accuracy of number plate detection, character recognition, and vehicle verification compared to manual methods. The third objective is to Facilitate Tax Collection by enabling the Bangladesh Road Transport Authority (BRTA) to collect taxes more effectively by automating the verification of tax-token status, reducing revenue losses due to non-compliance. Furthermore, this research seeks to Improve Traffic Enforcement by aiding law enforcement agencies in maintaining road safety and enforcing traffic regulations by identifying unregistered or stolen vehicles. Lastly, this research aspires to Support Research in the field of automatic number plate recognition (ANPR) by providing a dataset and methodology specific to Bangladeshi vehicle number plates, fostering further advancements in ANPR technology.

5 Proposed Methodology

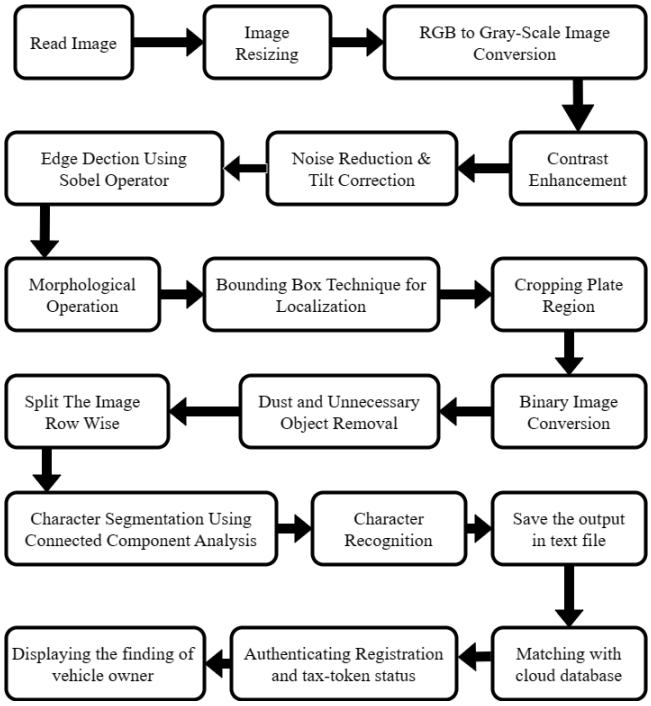

Figure 2: Overview of Proposed Method

This study proposes a novel technique that combines morphological image processing and template matching to automate the detection, extraction, recognition, and verification of Bangladeshi vehicle number plates. The proposed method consists of four primary components: [See in Fig. 2]

Step - 1: Pre-processing: Input images will be resized and converted to grayscale. Contrast enhancement and tilt correction techniques will be applied to improve image quality.

Step - 2: Extraction and Segmentation: This phase focuses on locating the number plate area and segmenting characters. It involves edge detection using the Sobel operator, followed by morphological operations like filling, dilation, and erosion

to localize the number plate. The Otsu method is applied for binarization, and character segmentation is accomplished using connected component analysis and bounding box methods.

Step - 3: Recognition: Character recognition is achieved through template matching. Recognized characters are stored in a text file for further processing.

Step - 4: Verification: The system verifies the extracted number plate against a cloud database containing registered vehicle details. If a match is found, the vehicle is marked as registered. Owner details are extracted from the database, and the validity of the car's tax token is checked.

5.1 Pre-Processing of the Image Captured

Images captured by a high-resolution camera are fed into the system. The steps of the pre-processing of the image process are given below.

Step - 1: Image Resizing: Initially, the input high-resolution RGB image will be resized to a standard size. This step ensures that all subsequent processing steps are applied consistently to images of the same dimensions.

Step - 2: Gray-scale Conversion: The RGB image is then transformed into a gray-scale image using Equation 1, The equation takes into account the red (R), green (G), and blue (B) channels of the image with specific weightings for each channel to create a single gray-scale image.

$$\text{Grayimage} = 0.299 \cdot R + 0.587 \cdot G + 0.114 \cdot B \quad \text{(Islam et al., 2021)} \tag{1}$$

This equation calculates the luminance of each pixel in the image, giving more weight to the green channel.

Step - 3: Contrast Enhancement: The gray-scale image will be subjected to contrast enhancement using the MATLAB function imadjust() which will improve the visibility of details in the image by adjusting the intensity levels. This results in an image with improved clarity.

Step - 4: Tilt Correction (Noise Reduction, Edge Detection, Radon Transform):

a. **Noise Reduction:** The enhanced gray-scale image is filtered using a low-pass filter named 'wiener2' with a 5x5 kernel. This filter helps remove adaptive noise from the image, improving the quality of subsequent processing steps.

b. **Edge Detection:** The Canny edge detector is applied to the filtered image. This step highlights edges or boundaries within the image. The edges are important for identifying the tilt angle.

- Noise reduction
- Gradient Calculation
- Non-Maximum Suppression
- Double Thresholding and edge tracking by hysteresis

c. **Radon Transform:**

The Radon transform is applied to the edge-detected image. The Radon transform is commonly used in image processing to detect lines or angles within an image. In this case, it is used to find the tilt angle of the image. (Chandra et al., 2017)

Affine Transformation:

Based on the tilt angle obtained from the Radon transform, an affine transformation is applied to the image. Affine transformations can include translation, rotation, scaling, and shearing. In this case, it is used to correct the tilt angle of the image, ensuring that it is aligned properly. The method can correct up to a 45° tilt angle.

5.2 Extraction and Segmentation of Number Plate

This is one of the important stages of an automatic license plate recognition system. This part of the proposed system performs two major tasks-localization and extraction of the number plate area and segmentation of the number plate characters.

Step - 1: Detect Edges using the Sobel Operator

Step - 2: Apply Morphological Operations (Filling, Dilation, Filling Again, and Erosion) to Detected Image

Step - 3: Apply the 'Bounding Box' Technique for Localization

Step - 4: Extract the Plate Using 'imcrop'

Step - 5: Convert to Binary Image using the Otsu Method

Step - 6: Resize the License Plate

Step - 7: Removal of Dust and Unnecessary Objects

Step - 8: Split the License Plate Row-Wise into Two Portions

Step - 9: Sequentially Locate Characters using Connected Component Analysis

Step - 10: Apply the 'Bounding Box' Technique for Character Segmentation

Step - 11: Extract and Resize Segmented Characters

In this step, the input is a tilt-corrected gray scale image. The Sobel operator will be applied to this image to detect edges. The Sobel operator calculates gradients in both the horizontal and vertical directions to identify areas of rapid intensity change, which typically correspond to edges in the image. It employs two 3x3 kernels to calculate gradients in both the vertical and horizontal directions. These gradient calculations help identify regions in the image where there are rapid intensity changes, indicating the presence of edges.(Islam et al. , 2020a) After detecting edges, the resulting edge-detected image will undergo a series of morphological operations. The operations include filling, dilation, filling again, and erosion, and they are performed seven times in total.

1. Filling fills in white pixels with black pixels within the edges.
2. Dilation expands the edges, making them thicker.
3. After dilation, filling is performed again.
4. Erosion then removes small white pixel areas from the edge boundaries.(Albashir et al., 2020)

These morphological operations will help refine the edges and roughly localize the license plate area. To precisely localize the license plate area, the 'bounding box' technique will be applied to the eroded image. The smallest possible rectangles (bounding boxes) are created around these areas. These bounding boxes define the boundaries of the license plate area. (Hossain et al 2018) Once the license plate area is localized using the bounding boxes, the actual license plate will be extracted. The extracted grayscale license plate image will be converted into a binary image using the Otsu method, which computes a threshold value based on the image's histogram to separate characters from the background. Pixels above the threshold will set to white, and those below will set to black, effectively binarizing the image. After binarization, the license plate image will be resized to a standardized size. This resizing ensures consistency in character size for further processing. Dust and unnecessary objects will be removed from the resized license plate image using functions like 'strel' and 'bwareaopen' in MATLAB. (Hossain et al 2018) After the extraction of the number plate, the double-line Bangladeshi number plate will be divided equally row-wise into two portions: the upper portion, which typically contains words and letters, and the lower portion, which contains digits. To segment the characters from both the upper and lower portions, the 'connected component analysis' technique will be used. This technique sequentially finds the location of the words, letters, and digits from left to right in both the upper and lower portions of the license plate. For the actual segmentation of characters within the license plate portions, the 'bounding box' technique

will be employed. This technique marks the segments with green-colored rectangles, effectively defining the boundaries of each character within the license plate. After marking the character segments with bounding boxes, the segmented characters are extracted from the license plate portions.. The segmentation process will follow the algorithm provided in Algorithm 1, which is designed to segment characters from the input image.

Algorithm 1 Segmentation of Characters

Require: Unnecessary object-removed image, I
Ensure: Resized segmented characters, P
1: $[m, n]$ = size of I; {Segment row-wise equally}
2: $Image1 = I(1 : m/2 + 14, :)$;
3: $Image2 = I((m/2) + 18 : 2 * m/2, :)$; {Segmentation of upper portion}
4: $[Q, N]$ = bwlabel($Image1$);
5: D = regionprops(Q,$' BoundingBox'$);
6: **for** $n = 1$ to Size($D, 1$) **do**
7: $Rectangle('Position', D(n).BoundingBox,' EdgeColor',' y',' LineWidth', 1)$;
8: **end for**
9: **for** $n = 1$ to N **do**
10: $[f, e]$ = find($Q == n$);
11: $P = Image1(\min(f) : \max(f), \min(e) : \max(e))$;
12: P = imresize($P, [42, 24]$);
13: **end for**{Segmentation of lower portion}
14: **repeat**
15: Repeat lines 4 to 13, taking $Image2$ as input.
16: **until** End of Loop
17: **return** P

5.3 Recognition of Characters

Character recognition is a crucial component in the development of an automatic number plate recognition system. This process involves identifying individual characters from segmented portions of license plates. The character recognition process involves the following steps: Each extracted character from the upper portion of the segmented license plate will be correlated with all the templates in the template dataset. If the correlation coefficient for a particular template exceeds a predefined threshold value (0.45), the system recognizes that template as a valid probable character. The template with the maximum correlation coefficient value is selected and saved as text in a string.

5.4 Verification of the Vehicle

Step-1: Connect with the Cloud Database: The verification process will begin by establishing a connection with a cloud database, which stores information about registered vehicles, including license plate numbers, owner details, and tax-token expiration dates.

Step-2: Match the Text File: The system retrieves a text file generated during the recognition stage, which contains the recognized license plate number. It then compares this recognized number with the data in the first column of the cloud database, which contains registered license plate numbers.

Step - 3: Vehicle Registration Status and Additional Information Retrieval: If there is no match between the recognized license plate number and the database, a message box will be generated, indicating that the vehicle is unregistered. This suggests that the vehicle may not be authorized to operate in the smart city. If a match is found between the recognized number and the database, the system proceeds to fetch additional information about the vehicle, such as the owner's name and address.

Step-4: Compare , Validate and Renewal Reminder of Tax-Token: The system will retrieve the present date and time and then compare it with the tax-token expiry date associated with the matched vehicle in the database. If the tax-token expiry date is greater than the present date, a message box will be generated, indicating that the vehicle is registered and that its tax-token is still valid. If the tax-token expiry date is earlier than the present date, a message box will be generated. It acknowledges that the vehicle is registered but reminds the owner that they need to renew the tax-token for the vehicle.

5.5 Data Collection

For the smooth running of the research, we'll prepare three kinds of datasets. They are – Bengali vehicle Number Plate image dataset, template dataset and car details' cloud database. We will create a dataset of around 500 images of Bangladeshi car license plates with both green and white background. The images will be taken at different illumination conditions, diverse angles and varying distances and stored in JPEG format. To recognize the characters, a dataset of Bangla alphabetic, numeric and word templates will be prepared. A cloud dataset containing the information of the vehicles will be prepared for this research using 'Google SpreadSheet'. The sensitive information about the vehicle and its owner will not be disclosed.

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