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Automatic License Plate Recognition System For Bangladeshi Vehicles Using Deep Neural Network

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Abstract. The goal of Automatic License Plate Recognition(ALPR) is localizing the license plate of a vehicle from an image and extracting text from it to recognize and track the vehicle. Each year, the amount of vehicles in Bangladesh is increasing at a significant rate. With the increasing number of vehicles, the Intelligent Transport System(ITS) has become essential. The Automatic License Plate Recognition System (ALPRS) is a key part of ITS. The ALPRS can also help monitor traffic, surveillance of certain areas, crime investigations, etc. This paper has proposed an optimal end-to-end approach for the ALPR system for Bangladeshi vehicles by experimenting with the various Deep Neural Network(DNN) models. These models have been trained and evaluated on our rich datasets of Bangladeshi vehicles and license plates. We have also introduced an algorithm that eliminates the need for the typical segmentation phase and generates properly formatted output efficiently. The final proposed system offers 99.37% accuracy in license plate localization and 96.31% accuracy in text recognition from the license plate(LP)s.

Keywords: ALPR, YOLO, SSD, DNN, bangla license plate recognition.

1 Introduction

ALPRS has been widely used by many smart cities worldwide, and there is an amazing opportunity for developing an end-to-end optimal system for this sector. ALPR is one of the major key concerns for building an ITS. Bangladesh is a fast-growing country. Its economy is increasing rapidly. As a result, the number of vehicles is also increasing in the big cities both in the private and trading sectors. As a result, traffic is also increasing on the roads and becoming difficult to manage. Moreover, increasing the number of vehicles also increases the tendency of criminal activities related to vehicles such as drunk & drive, hit & run, kidnapping, car stealing, driving in the wrong lane, etc as manually keeping track of these vehicles is very difficult. ALPR can reduce these problems and be helpful in toll collections, border securities, investigation of crimes, etc.

ALPR can be also helpful in an automatic parking space management system, in surveillance of any place or region.

An ALPRS has three main challenges as a whole. These are properly detecting a vehicle's license plate, segmenting the texts in the license plate, and recognizing the texts or characters or digits. Apart from these three challenges, another important challenge is to generate properly formatted output which is ready to use. This paper focuses on various ways of overcoming these challenges with the help of Deep Neural Networks and presents the most feasible solution for a complete ALPR system. Experimenting with different DNN models, we have come up with the most efficient & robust solution in every stage. Fig.1. demonstrates our full workflow. We have merged the segmentation phase with the recognition phase to make this process easy. By doing such, we can save a lot of time and computational effort. Finally, we have presented our custom algorithm, which is computationally efficient and generates a properly formatted output for our system.

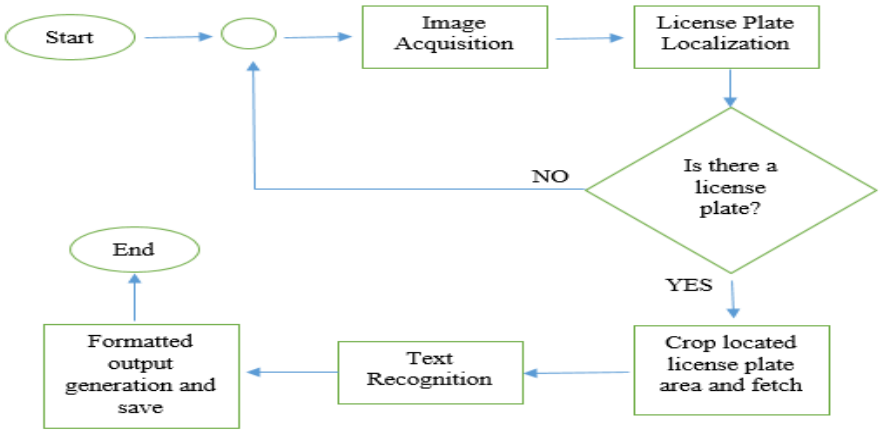

Fig. 1: Workflow diagram of our proposed system

Contributions of this article are as follows:

1. We have shown the performance comparison of various DNN models on the Bangladeshi license plates.
2. We have introduced rich datasets of images of Bangladeshi license plates from major cities of Bangladesh.
3. We have presented an optimal end-to-end solution for the ALPR system.
4. We have preprocessed the raw images in different DNN model-specific formats.
5. We have created a dataset containing almost 2800 images for localization and around 4000 images for text recognition stages.

6. Our proposed model offers one of the most promising result with 27 classes.
7. We have created a custom algorithm to emphasize properly formatted output generation.

The rest of the paper is organized as follows, section 2 is about Introduction to the Bangladeshi standard license plate, section 3 discusses the Literature review, discussion about Dataset is in section 4, Our proposed methodology is discussed in section 5, section 6 is about Results and discussion. Finally, section 7 has the Conclusion followed by references.

2 Overview of Bangladeshi Standard License Plate

Bangladesh Road Transport Authority (BRTA) is a regulatory body to control, manage and ensure discipline as well as to maintain safety in the road transport sector of Bangladesh. In 2012, as a part of digitalization, BRTA introduced a new vehicle license plate system called Retro-Reflective License Plate mostly known as vehicle digital license plate. Since then, it has become mandatory for vehicles to attach this license plate to the rear side. The new digital license plate is of mainly two categories: private vehicle's license plate and trading vehicle's license plate. The color combinations are a white background with black text for private vehicles and green background with black text for trading vehicles.

The license plate has two separate rows of texts, characters, and digits as shown in Fig.2. From the first row, the first word indicates the district name where the vehicle was registered. The second word is optional, if it is under the metropolitan area then it is used to indicate the area. The only character in the first row separated by a hyphen indicates the vehicle category.

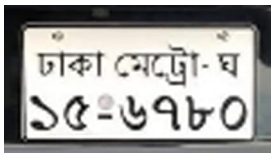

Fig. 2: BRTA Standard License Plate Format

Coming to the second row, the first two digits in this row is the class registration number of the vehicle, the next four digits again separated by a hyphen as a whole represent the serial number of the vehicle. It is mandatory to use Bangla language on the license plate.

3 Literature Review

The ALPR system has been a key sector of research for many years. Researchers worldwide have tried to develop this system in many ways. Quadri et al. [1] used

a Smearing algorithm for extracting plate region then used row and column segmentation for OCR to recognize text from it. Shidore et al. [2], used the Sobel Filter, Morphological Operations, Connected Component Analysis along with Vertical Projection Analysis. They also used the Support Vector Machine(SVM) for character recognition. Lekhana et al. [3] have shown an approach using Spectral Analysis along with Connected Component Analysis and SVM to recognize characters in the license plate. Astari et al. [4] have achieved significant accuracy according to their paper, where they proposed a system based on color features and a hybrid classifier that comprises a Decision Tree and an SVM. Wang et al. [5] have used Image Processing techniques for localization and segmentation parts and a CNN model for character recognition. Jain et al. [6] used Image Processing Techniques with Sobel Edge Detection then OCR to recognize the license plate. Lin et al. [7], used the YOLOv2 model for vehicle and the license plate localization, classic Image Processing operations for Segmentation, and a custom LPR-CNN model for character recognition.

Kumari et al. [8] proposed to use image prepossessing operations on the image then Contour Tracing & Edge Detection for LP localization. Then, they used neural network models for character segmentation and recognition. Ahmed et al. [9] and Choudhary et al. [10] mainly focused on the recognition part. In [9] have used Horizontal, Vertical projection, and gray level occurrence to extract edible text. On the other hand, [10] have used the CNN-LSTM model combined for character segmentation and recognition. They claimed a 99.64% success rate of their approach. Venkateswari et al. [11] concentrated on LP localization. To do so, they have used Horizontal & Vertical highest histogram value for extracting the Region of Interest (ROI). In [12], Surekha et al. claims to get 97% accuracy. They have done several image preprocessing operations then showed a comparison between Morphological processing & Edge processing for LP area extraction. They extracted the characters with Connected Component Analysis and recognized them using a supervised learning model.

Most of these proposed systems aren't properly applicable to Bangladeshi vehicle license plates. Because most of them are specific to a region, language, and type of license plate. Some previous work has been done for Bangladeshi vehicle license plates also. Nooruddin et al. [13] proposed the use of color features with MinPool and MaxPool features to detect license plates. Amin et al. [14] proposed a system combination of Edge Detection, Binary Thresholding and Hough Transformation for plate localization, and OCR for Bangla language to recognize text. Their accuracy is not noteworthy as well as that is not a generalized process. Baten et al. [15], in their paper, proposed a method that uses a special feature of the Bangla language called "Matra" and Connected Component Analysis for detection and segmentation of text then they used Template Matching for the recognition phase. However, they didn't reveal much about their dataset and accuracy. Abedin et al. [16] proposed using Contour Properties for both license plate detection and character segmentation. They proposed to use a CNN model for the character recognition part. They claim to get an accuracy of the total procedure 92% within 0.11s. However, their dataset mostly

includes private vehicles and they did not consider all the categories of vehicles and they did not focus on night conditions. Rahman et al. [17] only focused on the recognition task, so they had to manually cut the license plate then the characters from it, then they used the characters in a CNN model to recognize it. They used a dataset containing 1750 images. They had to do huge work to get the dataset.

Abdullah et al. [18] used YOLOv3 and then ResNet-20 in their paper. Their dataset contains 1500 images and 6400 character images for the localization model and recognition model respectively. They claimed to get 92.7% accuracy. But they have not extracted all text from the plate as it is only for Dhaka Metropolitan Area. So it fails to generalize for other cities. Dhar et al. [19] proposed a Shape Validation Technique to detect license plates, then tilt correction and Connected Component Analysis to segment different texts, characters, and digits. They used an Adaboost Classifier with two main features which are Histogram of Gradient(HOG) and Local Binary Pattern(LBP). They introduced a dataset of 2800 images of only 14 different classes for the recognition task. They achieved 97.2% accuracy. Sarif et al. [20] proposed a system that uses YOLOv3 for the plate localization and a custom segmentation algorithm to segment the texts, characters, digits from the plate which they later fed into a CNN model to recognize them. They gained 97.5% recognition accuracy. However, they only tested on 16 different classes which are not sufficient for the real scenarios of Bangladeshi vehicle license plates. Moreover, they tested mostly on private vehicles of Dhaka city only which makes their claim more vulnerable in the case of the trading vehicle license plates. Saif et al. [21] proposed to use the YOLOv3 model in number plate localization and the recognition stage. They used a small dataset containing only 1050 images of private vehicles. They claim to get 99.5% accuracy. Their claim completely fails in the case of trading vehicle license plates which is absent in their dataset. Moreover, they measured accuracy in the binary fashion of the license plate as a whole.

In [22], Azam et al. mainly focused on removing noise from images for detecting LP regions. They gained 94% detection accuracy. They used a method with frequency domain mask to remove rain stroke, contrast enhancement method, Radon transform for tilt correction, and image entropy-based method to filter LP regions. Hossain et al. [23] proposed a system depending on various image processing operations. They proposed to use the Sobel edge operator, dilation, erosion, boundary features, horizontal & vertical projection to extract LP regions. Then dividing the extracted LP region into two halves, they used boundary features to segment the character and Template Matching to recognize them. However, their system fails in case of ambiguous character recognition and more than 10 degrees tilted image. They claimed 90% accuracy. Chowdhury et al. [24] extracted the LP region based on color information, segmented that in two halves using centroid information, and extracted characters using bounding box parameters. Then, they used SVM to recognize characters. They claimed 99.3% recognition accuracy. But they only used private vehicle images, their system struggles when LP isn't in focus & image isn't ideal and tested only on 14 classes. In [25],

after preprocessing, Horizontal & Vertical projection with geometric properties were used by Islam et al. to extract LP regions. Then character localization is done with Connected Component Analysis and bounding box technology. SVM is used to recognize characters using the features extracted with HOG. They got very good recognition accuracy but they ignored non-ideal conditions. Their system fails when the image resolution isn't high and struggles to detect trading vehicle's LP. Ahsan et al. [26] proposed a system that uses Template Matching to localize LP region, Spatial Super Resolution technique to enhance the image, Bounding Box method for segmenting characters, and AlexNet to recognize them. They attained 98.2% accuracy which seems to be currently one of the highest. However, they didn't reveal much about the number of classes AlexNet was trained on. Also, the Template Matching technique often finds it hard to detect a target when that is tilted in an image.

4 Dataset

Fig. 3: Images in Plate Localization dataset

Fig. 4: Images in Text Recognition dataset

One of the main contributions of this paper is the rich datasets for both localization and recognition of the Bangladeshi license plate. Our first dataset contains almost 2800 images for localization shown in Fig.3. The second dataset contains around 4000 license plate images cropped from our first dataset shown in Fig.4 which are the most so far in this sector. We have split our datasets into 70:15:15 and 85:10:5 for training, validation, and testing purpose in license plate localization and text recognition stage respectively. Our datasets contain images from 4 different cities of Bangladesh: Dhaka, Khulna, Chattogram, Jashore including 12 different vehicle categories license plates from both private and trading vehicles. Our datasets are diverse enough and cover almost every possible condition,

angle, and environment. To create our datasets more diverse we have gathered images from different sources. From Nooruddin et al. [13] we are given their dataset of only trading vehicles. Most of the private vehicle images are used from this paper Rahman et al.[27], and the rest of them are collected by us.

5 Our Proposed Methodology

Our full system is divided into 3 major parts. First, license plate localization from an image. Next, recognizing text, characters, digits from the license plate and finally, presenting a formatted output.

5.1 License Plate Localization

Many have proposed to use Color Features [4], [13], Sobel Edge Detection [2], [6], [14] , Image Processing Techniques [5], Deep Learning Models [7], [18], [20], [21]. Generally, image processing operations are time-consuming and computationally expensive. Apart from that Image Processing Technique doesn't generalize for every situation. So we prefer DNN models over them. However, some researchers also used DNN models previously those are not state-of-the-art models anymore. Here we have implemented some new pre-trained DNN models and tried to compare their performances in section 6.

YOLOv4 is one of the latest versions of You Look Only Once(YOLO), a real-time object recognition system that can recognize multiple objects in a single frame. YOLO is a one-stage object detector. YOLOv4 has surpassed its ancestors in terms of accuracy and speed [28]. Single Shot Detector(SSD) [29] is designed for real-time object detection, it uses VGG16 [30] to extract feature maps and small convolutional filters to detect objects. It achieves accuracy close to that of Faster R-CNN [31] in terms of lower resolution images.

We have implemented SSD MobileNet V2 FPNLite 320x320, SSD MobileNet V1 FPN 640x640 and SSD Resnet50 V1 FPN 640x640. EfficientDet [32] family is the successors of the EfficientNets. EfficientDet detectors are single-shot detectors much like SSD. Their backbone networks are ImageNets pre-trained EfficientNets. They use BiFPNs to create bidirectional feature fusion to detect objects. We have implemented EfficientDet D0 512x512, EfficientDet D1 640x640, EfficientDet D2 768x768 in this stage.

5.2 Text Recognition

Recognition of texts in the license plate region plays a crucial role in building an ALPR system. Most of the previous researchers devoted their effort to segmenting different texts in the license plate area in different ways and then recognizing those segmented parts separately. However, this is a somewhat lengthy process and we have proposed an idea to merge this two-part: segmentation and recognition into one.

From the previous stage, after localization, we get the desired license plate region cropped from our model. This cropped image is then used in this stage to recognize texts on the license plate. We have considered each separated text as an object and then tried to detect them in the license plate. By doing so we have eliminated the need for any other segmentation algorithm. In this stage, we have implemented various models and their performances are discussed in section 6. Implemented models are YOLOv4, SSD MobileNet V2 FPNLite 320x320, SSD MobileNet V1 FPN 640x640, SSD Resnet50 V1 FPN 640x640, EfficientDet D0 512x512, EfficientDet D1 640x640, EfficientDet D2 768x768.

5.3 Formatted Output Generation

In this part, we have proposed a unique solution that plays a key role in eliminating the need for any segmentation part and yet generates the standard BRTA license plate number form.

From the Text Recognition stage, the output is provided for each image in 3 different lists. One list contains the coordinates of the individual characters and words in the image, the second list is of confidence score for each of the coordinates, the third list is the class id of each of the predicted characters and words. Using these lists, we have developed an algorithm that generates output from each image in BRTA standard format and stores them in a CSV file.

Algorithm 1: Formatted Output Generation

```
Result: Set of characters from the license plate as a string
Push 0-9 numbers as a string in a list NBR;
Push class names in a list CN where indexes are according to class id;
Applying non-max suppression on the predictions and get the indexes
 into a list IDX;
while i from 0 to length(box_coordinates) do
    if i in IDX then
        Get (x,y,w,h) from box_coordinates list;
        Push (x,y,w,h,i) into OBJ list;
    else
        Continue;
    end
end
Sort OBJ;
while obj in OBJ do
    Index_no = obj[4];
    if CN[Index_no] in NBR then
        Append CN[Index_no] in PN string;
    else
        Append CN[Index_no] in PP string;
    end
end
Store PN and PP into a CSV file
```

6 Results and Discussion

(a) (b) (c)

Fig. 5: 5a Output from license plate localization stage 5b Output from text recognition stage 5c Formatted output in a CSV file

We have used Google Colaboratory which provides a single 12GB Nvidia Tesla K18 GPU RAM, for training and evaluating our models. However, we have labeled the images of our dataset for different models in a local machine. Fig. 5a shows the output from the license plate localization stage. Fig. 5b shows the output from the text recognition stage, and finally, Fig. 5c shows the formatted output. For the evaluation of the models, we have considered two main metrics which are mean average precision(mAP) for 0.5IoU and Recall.

Table 1: Performances of different models on localizing license plate from images

Metric	Model						
	EfficientDet D0	EfficientDet D1	EfficientDet D2	SSD MobileNet 320 Lite	SSD MobileNet 640	SSD Resnet50 640	YOLOv4
mAP	0.9736	0.9956	0.9831	0.9871	0.9451	0.9843	0.9937
Recall	0.7393	0.7248	0.6854	0.7665	0.7111	0.7579	0.9800

Table 2: Performances of different models on text recognition from images

Metric	Model						
	EfficientDet D0	EfficientDet D1	EfficientDet D2	SSD MobileNet 320 Lite	SSD MobileNet 640	SSD Resnet50 640	YOLOv4
mAP	0.9089	0.9184	0.8940	0.9254	0.9448	0.9359	0.9631
Recall	0.6869	0.7334	0.7127	0.7407	0.7477	0.7437	0.9800

Table. 1 shows the result from different models that we have trained and evaluated for the license plate localization. From the table, we can see that in the license plate localization stage both YOLOv4 and EfficientDet D1 640x640 have performed very well. But as the recall of YOLOv4 is much higher than that of EfficientDet D1 640x640, YOLOv4 is surely a better choice here. Similarly from Table 2, we can conclude that YOLOv4 has performed significantly better than other models in terms of both metrics.

Table 3: Accuracy comparison with other approaches

Method	Accuracy(%)
[23]	90
[17]	92.7
[18]	97.2
[19]	97.5
[26]	98.2
[24]	99.3
Our proposed method	96.31

From the above discussion, it is clear that using the YOLOv4 model in both the license plate localization and text recognition stage can be combined to provide the best solution to the automatic license plate recognition for Bangladeshi vehicles. Moreover, we have compared our system with previously existing systems and it has proven to be one of the best solutions for this type of system keeping in mind that no existing system has been evaluated on 27 different classes before.

From table. 3 and considering our diverse datasets we can confidently conclude that our proposed method can perform significantly better than most other method previously proposed in a real-life scenario.

7 Conclusion

This paper is mainly focused on finding the best solution for an automatic license plate recognition system for Bangladeshi vehicles. To do so, we have used 7 different methods in two different stages and successfully come up with the optimal and efficient solution to this problem. Using the YOLOv4 model in both the license plate localization and text recognition stage offers the most promising result so far. Besides, we have successfully generated the BRTA standard format from the result and are able to store it in a CSV file. Moreover, this paper also suggests a computationally efficient way to eliminate the segmentation part using our custom algorithm along with the YOLOv4 model. Apart from that, here we have also introduced two rich and diverse datasets. These datasets contain images from four major cities of Bangladesh and the 12 common vehicle category

license plates in Bangladesh. With the YOLOv4 mode, this system has managed to gain 99.37% and 96.31% license plate localization and text recognition accuracy respectively. However, in the license plate localization stage, the YOLOv4 model is mostly trained on daylight condition images. So this system may not perform as expected in the night condition until more of those conditions images are included in the dataset for training. The whole system can be made more generalized by adding more images to both datasets. Moreover, Running the system on a GPU will provide the best Frame per Second(FPS) in case of any video footage. There is a scope of research for future researchers to prevent this system from storing similar license plate numbers from consecutive frames of video footage. Considering the whole methodology, performance, and least limitations of this system, we believe that we have found the state-of-the-art approach and it shows satisfying results for an end-to-end Bangladeshi license plate recognition system.

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