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A New Approach For Vehicle Number Plate Detection

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Abstract— **Identification of cars and their owners is a tedious and error prone job. The advent of automatic number plate detection can help tackle problems of parking and traffic control. The system is designed using image processing and machine learning. A new system is proposed to improve detection in low light and over exposure conditions. The image of vehicle is captured, which is preprocessed using techniques like grayscale, binarization. The resultant image is passed on for plate localization, for extracting the number plate using CCA (Connected Component Analysis) and ratio analysis. De-noising of number plate is done using various filters. The characters of the number plate are segmented by CCA and ratio analysis as well. Finally, the recognized characters are compared using techniques such as SVC (linear), SVC (poly), SVC (rbf), KNN, Extra Tree Classifier, LR+RF, and SVC+KNN. The proposed techniques help the system to detect well under dim light, over-exposed images and those in which the vehicle is angled.**

Keywords—Number plate detection, OCR , median filter , image processing , cca , image recognition, number recognition

I. INTRODUCTION

Automatic Number Plate Detection is a subject undergoing intense research for quite some time. In this method, the computer recognizes the string of characters from a vehicle's number plate. This system has a wide range of applications in the field of security, parking, charging for over speeding, identification of stolen cars, etc. The system is built under six modules as followed: Preprocessing, Threshold Optimization, Plate Localization, De-noising, Character Segmentation and Character Recognition. In our background study we studied the various techniques that have been developed to improve this process over the years. In Reference [1], author uses techniques like normalization, edge detection, median filter, character segmentation and OCR. Author in [2] captures the video of the vehicles and selects frames from the video in which the vehicle can be seen clearly and converts it into grayscale. It uses Sobel-edge detection algorithm to detect edges and Normalized Cross-Correlation for character recognition. The authors in [3] are using a video to detect number plate and have mentioned an excellent technique called unsharp-filter Masking which is used to remove noise such as rain and fog and their results are quite good. The authors [4] have proposed the use of a mobile based software solution that has Automatic number plate detection capabilities to help in vehicle identification and vehicle registration, which is very rare. The Author in [5] first converted RGB image to grayscale then removed unwanted edges, followed by infill function to get clear binary image. For segmentation, bounding box technique was utilized. In reference [6], the authors have used Sobel method for edge detection, vertical and horizontal band clipping for preprocessing, and Hough transform for skew correction and segmentation. The Author in [7] first convert the colored image to grayscale using cvtColor method, followed by localizing of plate and artificial neural network for edge detection and segmentation. Section II describes the methodology of the approach. The implementations and results are presented in section III. In the last section, we have concluded the work.

II. METHODOLOGY

The entire design of the process can be seen in Fig. 1. All the stages in the diagram are explained in detail as follows.

A. Preprocessing

1) Gray Scale Conversion

Gray scale conversion is the first and the most important step in image pre-processing. The main reason why it is used instead of working on colorful images directly is that RGB (color) has a 3-dimensional property (24-bit size) which translates to a larger size being trained by the software each time. The color information is noise in image processing as it makes it difficult for the software to pre-process the image. On the other hand, gray scale has less size and is acceptable in most of the algorithms.

2) Binarization

The Binarization Method converts the image into an image in which the pixel can only have 2 values – 0 or 1, i.e., a black and white image. The result of OCR (optical character recognition) is highly dependent on binarization. More accuracy is achieved in character recognition using a good quality binarized image as the original image consists of noise.

Otsu Binarization Method uses automatic binarization level decision and global threshold technique, based on the shape of the histogram. This method calculates a measure of spread for the pixel levels by scanning all the possible threshold values. This has been a widely used technique used for image detection.

Majority of the authors in this area use this method to calculate the threshold value. We have proposed a new method for low light/bright conditions where Otsu's method fails. We decrease or increase the Otsu's threshold up to 2.5 times the original threshold value by dividing/multiplying with numbers between 1.1 and 2.5 with increments of 0.1 each time, until suitable threshold is achieved. If the image is dark, it would be

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helpful for algorithm to reduce the threshold value. It is done by dividing the threshold by a small value between 1.1 and 2. Sometimes the image can also get too bright and hence will lose the black boundaries of the number plate which will cause hindrance in the next stage, i.e., the detection of number plate. To solve this, increasing the threshold by multiplying it by values like 1.2, 1.5 or 2 will help us regain the crucial black boundaries. Our algorithm will test a range of predefined range of threshold values until it gets us the required number of characters in the final stage. The threshold that gives us the maximum number of characters in the end will be selected.

B. Number Plate Localization

1) Connected Component Analysis(CCA)

Plate localization is concerned about segregating the number plate area from the rest of the image. CCA considers the image in the form of pixels. Since at this stage the image is binarized, image can be said to be composed of 2-pixel values, 0 and 1, to represent white and black regions in the image respectively. CCA will group regions having similar pixel intensity values (by default 0 valued pixel) together, hence revealing the connected regions. We use this method because license plate is one such connected region Using bounding box in python we were able to draw rectangles representing the "connected regions" classified by CCA. Our next task is to remove the unnecessary connect regions.

2) Ratio Analysis

To shortlist the falsely selected candidates for number plate we can introduce new parameters. If we will be detecting number plates for the same scenario every time, for example, an institution gate.

If we assume that the position of the camera and the car will be roughly be same every time, we can say that the ratio of height and width of the number plate to the height and the width of the entire image, respectively, will lie in a defined range. Some more properties like the rectangular shape of the number plate and width being greater than the height were also incorporated in the shortlisting.

The result of this analogy can be seen in the results. The number of connected regions dropped to 1-2 regions from many regions. One of the regions was correctly identified as the number plate. The false region could be eliminated at later stages while extracting individual characters.

C. Noise Reduction

Noise Reduction is done at this stage because the following techniques were hindering with the localization stage. The other reason is doing noise reduction at only the number plate will reduce the processing time. The following techniques help in removing dust, water and other noise which can often appear on our number plates.

1) Unsharp Masking Filter

This technique is used to remove noise by creating a mask of the original image using the negative image (blurred). This mask is then merged with the original image, giving an image better than the original one. For creating the mask, we use the Gaussian blur.

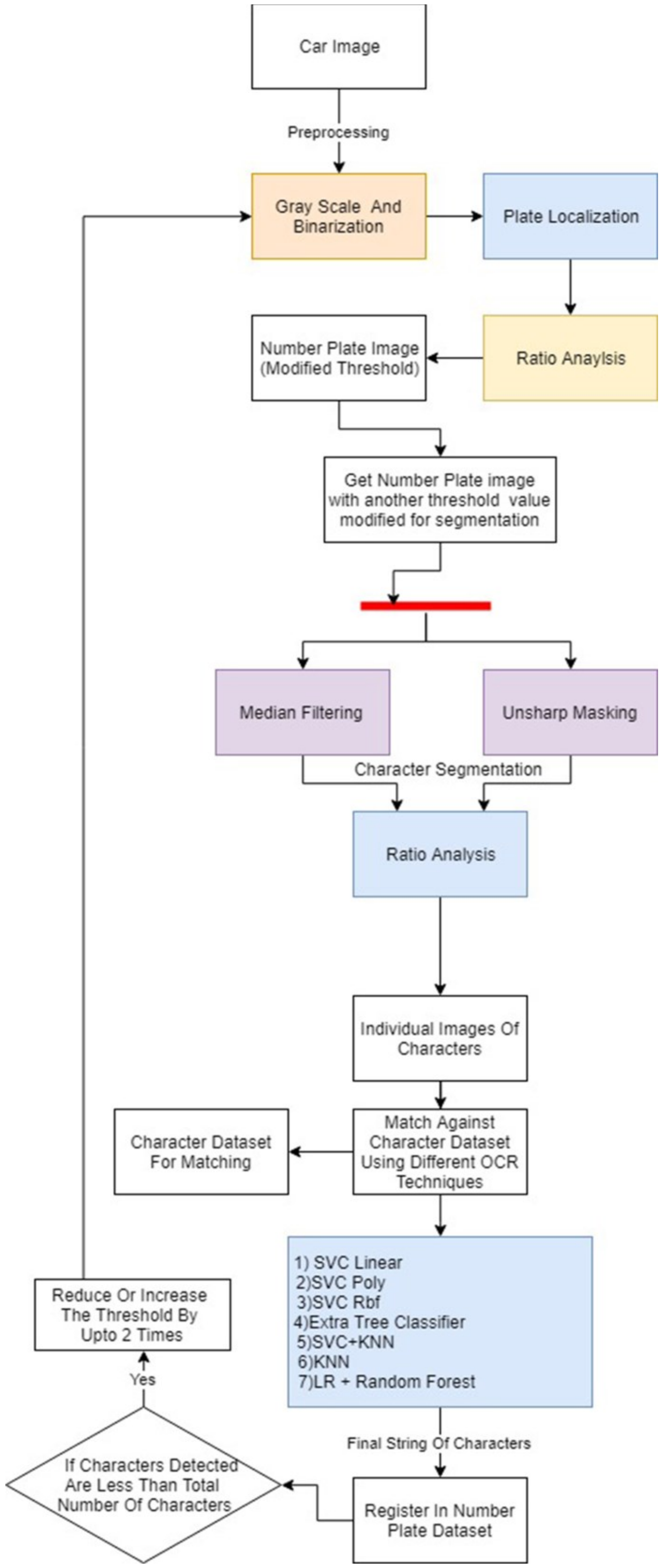

Fig. 1. Detailed design of the process

We have used the following formulae for unsharp masking:

$$x = i - s * b \quad (1)$$

$$r = i + x \quad (2)$$

where, i = image of the car, s = unsharp strength, b=negative image, x = mask, r = resultant image.

2) Median Filter

Median filter is an excellent and widely used noise reduction technique to get a clean image. This technique works on the principle of calculating the median intensity value of the pixels and using it as the output intensity value. The calculation is done using a window which slides along the image.

D. Character Segmentation

Character segmentation is a crucial step in image processing. It helps us in separating the characters on the plate so they could be passed on to the next stage for recognition.

Threshold that was modified for locating the number plate may not serve us the best in segmentation also. This is the reason we can modify the threshold again at this stage for optimal segmentation. This is especially important for low light/super bright images.

1) CCA with Ratio Analysis

In the same way we localized the plate using CCA, we can also find the characters. Characters are also a connected component.

Since characters are black and our algorithm checks for white connected components, we can invert the image. This will find us all the characters. Ratio analysis is used again for filtering out false candidates found in CCA.

Since the ratio of height and width of the characters on the number plate to the height and the width of the number plate, respectively, will lie in a defined range. We define the maximum and minimum ratio here to selected characters. Bounding boxes feature was used to draw rectangles around these characters

E. Optical Character Recognition

We have used various supervised machine learning techniques to recognize the characters on the number plates. All the techniques are first trained to know how the various characters look like. We have used 20 images of different looking images for each alphabet and number. We first convert the images into a one-dimensional array containing all the pixels. Each of those pixels is used as a different feature for training the model.

1) Support Vector Machine

Support Vector Machine (SVM) is powerful for outliers. It has the capability of dealing with high dimensional data. We will be using SVM with the following kernels:

a) Linear

A hyper plane is written as the set of points $\vec{y}$, in which the hyper plane's normal vector is $\vec{r}$. Hyper plane's offset from the origin along the normal vector $\vec{r}$ is u/||$\vec{r}$ ||.

$$\vec{r}.\vec{y} - u = 0 \quad (3)$$

b) Polynomial

Polynomial kernel is defined by a degree l. We obtain from training or test samples, feature vectors z and m and $q \geq 0$ is a parameter which is responsible for trading off the effect of lower order terms with upper order terms.

$$k(z, m) = (z^T m + q)^l \quad (4)$$

c) Radial basis function (RBF)

Here we have the distance (squared Euclidean) between the 2 vectors is equal to $||n-n'||^2$. Free parameter is represented by σ .

$$k(n,n') = e(-||n-n'||^2)/2\sigma^2 \quad (5)$$

2) KNN

K-Nearest Neighbours (KNN) takes k number of nearest training examples in the feature space and classifies the output according to the value which is most common among its neighbours.

3) Extra Tree Classifier

This technique works by averaging the values obtained by fitting sub samples of the dataset into decision trees that are randomized.

4) Logistic Regression

It is an easy algorithm performing very fine on a wide range of problems. We assume x_1 and x_2 as the input variables at the training instance.

Y_0, $Y_1$and Y_2 are assumed to be coefficients that are updated using Eq.(7), the output of the model used for making 'prediction' is computed using Eq.(6):

$$Prediction = 1/(1 + e^{(-(Y_0+Y_1*x_1+Y_2*x_2))}) \quad (6)$$

Let 'B' be the coefficient to be updated, 'y' be the output variable, 'x' be the input value for the coefficient, and 'α' be the parameter known as 'learning rate' which is specified at the beginning of the training, which controls the amount of changes in the coefficients and hence in the model. The coefficients $B_0, B_1,$ andB_2 are updated to new coefficient values as given by in Eq.(7):

$$B = B + a*(y-P)*P*(1-P)*x \quad (7)$$

where, P is prediction.

5) Random Forest

Random forest is an ensemble algorithm which creates multiple decision trees for training and outputs the class that is the mode of values given by all decision trees. Random forest aggregates many decision trees to give more accurate results.

6) Fusion of Above Techniques

Ensembles are one way to improve your accuracies on the dataset. Here voting method is being used which combines different types of techniques and their predictions to give an improved and better results.

Here, a combination of SVM (linear classifier) with KNN and a combination of logistic regression with Random Forest are implemented using ensemble by combining two techniques that leads to overcome the shortcomings of individual technique.

III. IMPLEMENTATIONS AND RESULT ANALYSIS

A. Preprocessing

1) Gray-scaling and Binarization

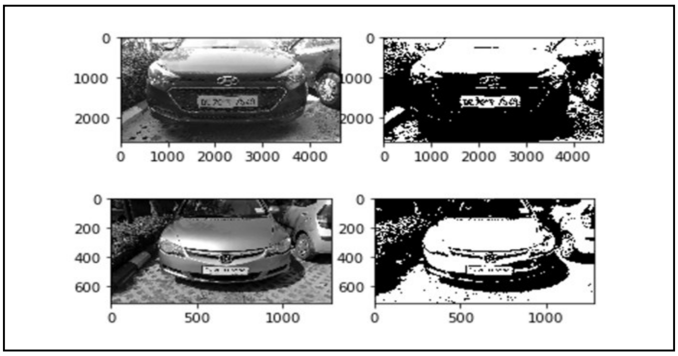

Fig. 2. Grayscale(left) and Binarization(Right)

Fig. 2. Shows an image during the grayscale and binarization stages. However, in different lightening situation, the Otsu threshold value will not yield the correct picture for which we are looking for. Therefore, we check the preprocessed image with different threshold values. Fig. 3 shows a car image in which binarization was done using Otsu-threshold. This picture was taken in a low lightening parking lot.

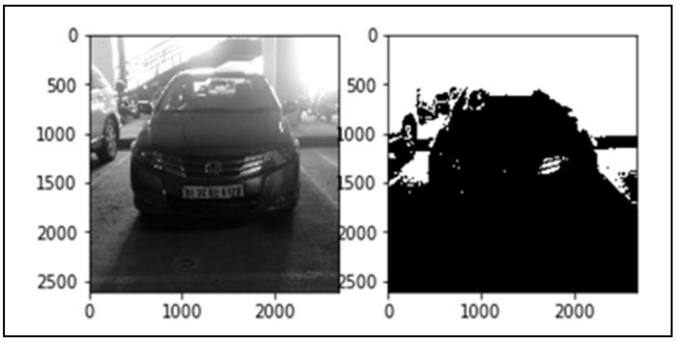

Fig. 3. Otsu threshold in dim light conditions

As you can see, the Otsu threshold value caused most of the pixels to turn black and for that reason the number plate is undetectable. For this reason, we designed our algorithm to run through different threshold values to find the optimal value that produces a character string in the end of the process. In this case, by reducing the threshold by ½ that helps to produce a clearer number plate than the last image as shown in Fig. 4.

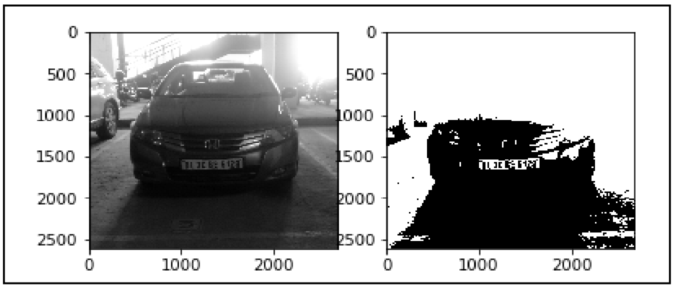

Fig. 4. Modifying threshold

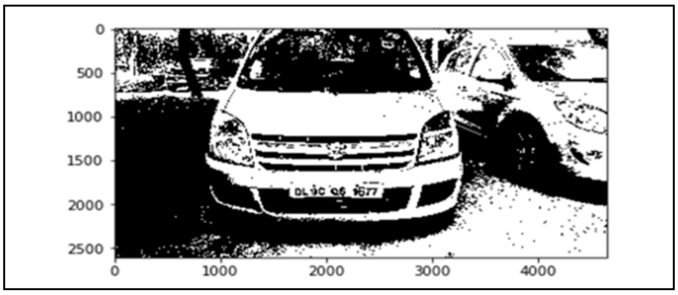

Fig. 5. Otsu Threshold in over-exposed images

As you can see we can get the boundaries of the number plate, but we won't be able to recognize the characters since the number plate is not clear here. As discussed earlier, we use the coordinates of the number plate located here on another image where a different threshold that recognizes the maximum characters will be chosen.

One of the other problems can be over-exposure in conditions such as sunlight as shown in Fig. 5. Such an image is shown below where the image is so bright that the number plate will lose its black boundaries during binarization. Our program will also test this at different threshold values and will settle for a value higher than the normal threshold.

In this case it gives the correct output if we increase the threshold by 1.5 times. This will darken the image to retain the boundaries of the number plate hence resulting in localization of the number plate as shown in Fig. 6.

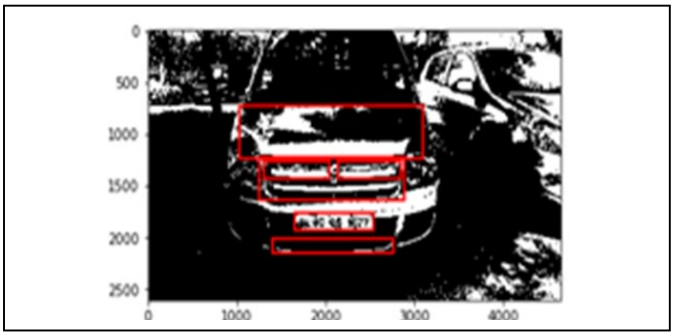

Fig. 6. Binarization with modified threshold for over-exposed images

B. Localization

1) Candidate Selection By CCA

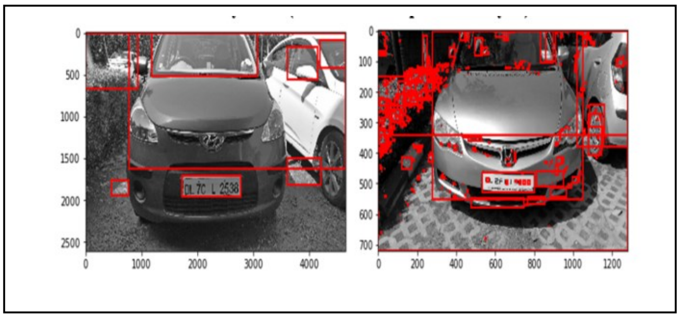

Fig. 7. Localization by CCA

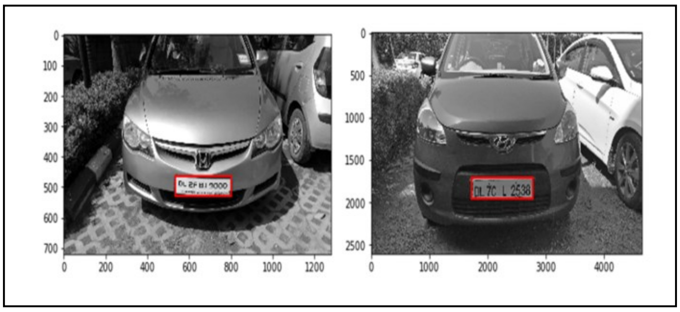

Fig. 8. Candidate Filtering using Ratio Analysis

As observed in Fig. 7. there are many candidates selected. By using ratio analysis as mentioned in section II, we reduce the number of candidates drastically as shown in Fig. 8.

Even if there are false candidates, they will be eliminated at a later stage because they would not produce any actual characters. CCA also localizes number plates that are skewed/angled like follows. Percentage of Cars Localized: 92.7%

Fig. 9. Localization with cars at an angle

C. De-Noising

As you can see Unsharp Masking improves the number of characters segmented. The characters D and L are segmented in the next stage when unsharp masking is done, as seen in figure 10.

Median filter performs better during the segmentation of all the characters in the same number plate unlike in unsharp masking, as seen in Fig. 11.

Fig. 10. With unsharp masking(top) without unsharp masking(below)

Fig. 11. With(top) and without(below) median filter

D. Character Segmentation and Recognition

The result of character segmentation is achieved by using CCA and ratio analysis that can be seen in Fig. 12. In the following Tab. 1, we have compared the percentage of characters recognized out of the segmented characters. We observe that SVC (Linear kernel) is able to correctly identify 97.1% of segmented characters.

TABLE I. RECOGNITION ACCURACY OF SEGMENTED CHARACTERS

Technique Name	Accuracy
SVC (Linear Kernel)	97.10%
SVC (Poly Kernel)	85.70%
SVC (RBF)	93.00%
KNN	87.50%
Extra-Tree	95.70%
LR + RF	93.90%
SVC + KNN	92.60%

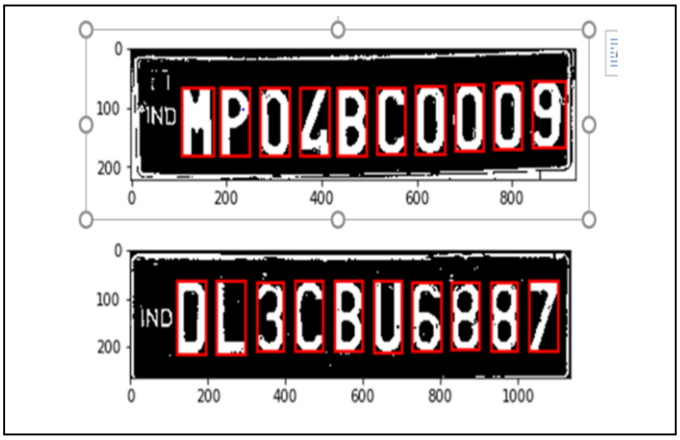

Fig. 12. Character Segmentation

IV. CONCLUSION

The number plate recognition process has been employed, and accuracies of the different techniques and limitations of the proposed design have been discussed. The new proposed technique "Threshold Modification" proved to be successful for detecting number plates even in low light conditions, extreme brightness which otherwise failed in previous machine learning systems. Various OCR techniques such as LR+RF, SVC+KNN, Extra Trees, SVC (Linear, Poly, Rbf, Linear.svc) have been applied and compared, with SVC (Linear) giving the best accuracy of 97.1% segmented characters correctly recognized. The accuracy was not compared with other techniques since the testing was done on a completely new dataset made from vehicles at JIIT institution and the improvement in detection is only expected in low light or bright(sunny) conditions. The system is also successful for detection number plates from skewed angles. Our aim is to make registration of vehicles in Jaypee Institute of Information Technology.

There is a need to expand the types of vehicles that can be detected: trucks, buses, scooters, bikes. The design should also provide help in toll plaza, parking lots, theft of vehicles and in accidents. This technology can be further improved to detect the crashed vehicle's number plate in an accident and alert the closest hospital and police station about the accident, thus saving lives. India being the 4th largest auto market that requires Number plate detection to assist traffic authorities and curb criminal activities.

V. REFERENCES

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