This full-text paper was peer-reviewed and accepted to be presented at the IEEE WiSPNET 2017 conference.

A Robust Algorithm for Morphological, Spatial Image-Filtering and Character Feature Extraction and Mapping Employed for Vehicle Number Plate Recognition

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***Abstract*—This paper illustrates the implementation of a character feature extraction, classifier and an effective mapping algorithm applied on images of vehicle license plates, using non-linear feature extraction and spatial mapping. A novel algorithm for low-level visual feature extraction has been presented, highlighting non-linear morphological operations with structuring, filtering, erosion and dilation techniques. Filtering and enhancement of raw image for key feature extraction and recognition by edges by sobel, canny and Fuzzy logic, convolution, median filtering and scaling image for boosting visual spatial features has been performed. Template matching using thresholding by effective feature mapping and semantic feature matching methods with pre-fed datasets has been accomplished as an application to image computing. The results obtained are tabulated and an accuracy of 79.30% using the above mentioned algorithm is reported. The images henceforth have been exposed to standard channel noises and thereafter compared for loss of information and overall structure. Comparison methodologies used are MSE and PSNR values and Structured Similarity Index (SSIM). The accuracy of results thus obtained are reported, suggesting the robustness and effectiveness of the algorithm. Image acquisition is accomplished by a remotely controlled android platform based device integrated with the MATLAB platform in real-time. The acquired number-plate data is transferred into a text file for creating a vehicle index log, critical for security systems.**

***Index Terms*—extraction, thresholding, morphological, erosion, fuzzy, template, SSIM.**

I. Introduction

In this paper, we aim to introduce an automatic vehicle number plate recognizing and saving system, with an acceptable error rate and robustness, adaptable to various environmental variables and conditions, while saving this number and comparing it with a pre-defined database of registered vehicle's numbers in real time.

The program uses an algorithm which is based on edge detection methods, thresholding methods and segmentation as well as various filters and morphological tools to reliably extract the number from a raw image of a vehicle's number plate, within a limited processing time, using a digital image acquisition hardware device at front-end, while using MATLAB software to perform these tasks at back-end. The algorithm, thus, focuses on the overall system's reliability, adaptability and faster processing speed while making it automated and with no human intervention, to the maximum extent. The novelty of this paper lies in the fact that image acquisition of a vehicle's number plate has been performed by a usb webcam and an android-device based camera, which can be controlled remotely using MATLAB, and then perform image processing on that snapshot using various morphological filters which have been used by Ozbay et al [1], [2] in some earlier models for vehicle number detection. In addition to this, we have incorporated a Fuzzy-engine based filter [3] to specifically extract the essential characteristics in the image and relinquish the ineffectual parts of the image, thus providing an image with more relevant details. On the next step [4], it aims to read the vehicle number and save it with time stamp in a .txt file format so as to be easily accessible to various authorities. This is, thus essentially an Automated Vehicle Log, which can be extended to varying applications such as automated parking systems at various locations, security alert systems at sensitive institutions, even identifying and tracking stolen vehicles automated entry systems for houses.

II. Procedure

The Real-Time, remotely controlled Automated Vehicle Number Logging and Database System has been divided into the following sequential steps:

A. Image Capture Using a Remotely Controlled Webcam or Android-based Device Through a Local Wireless Network

Image acquisition is an important event and while there might be a need for a camera installed at a key location, controlling it manually or even through wires is not a feasible method in many places where this vehicle number plate recognition system is used. We therefore developed proper (see Fig. 1), uninterrupted and dedicated channels to counter the issue of data loss or spoofing during communication between the camera and the system running MATLAB software. Here we explored two methods to supply raw image data into the MATLAB program: using a usb-camera and using any android based device. The resolutions as well as ambient light conditions, and background noise effect the overall image structure and thus might introduce errors at the latter stages. But we managed to integrate a novel real-time, remotely controlled, android-platform based video surveillance system

978-1-5090-4442-9/17/$31.00

Fig. 1. Flowchart of NPR algorithm.

using MATLAB software as its data receiver and controller. The speed of channel transmission was adequate and failure rate was minimal. Communicating on a wireless network, the image acquisition device and the MATLAB system can even run without any external network requirements.

B. Extraction of Number Plate Region

In the first step, the number plate is resized and converted from RGB Image (captured image) to Gray Scale Image. Then removal of noise from Gray Scale Image is done using median filtering. Here morphological operations (dilate and erode) is used for edge detection of characters. *Also, it is here that a new filtering technique, fuzzy-filtering has been used and applied to see improved results in some cases*. After that we get edge enhanced image. Then 'imfill' function is used to fill the holes so that we get a clear binary image. Convolution is done to brighten the edges. Again morphological operation is applied on binary image.

C. Segmentation and Recognition of Plate Character

Segmentation is done by using bounding box technique. The bounding box is used to measure the properties of an image region. The basic step in recognition of vehicle number plate is to detect the plate region. Here we have performed template matching of segmented image with pre-stored bitmap images of alphabets and numbers so that we only get the number plate of the vehicle.

D. Display Vehicle Number

After undergoing the above steps, the number plate is sent to a .txt file for keeping a log of all the vehicles entering. We intend to make a comprehensive table of the vehicles along with timestamp onto a file. This notepad file is the displayed on screen for a user to verify it with original image in real time, if required.

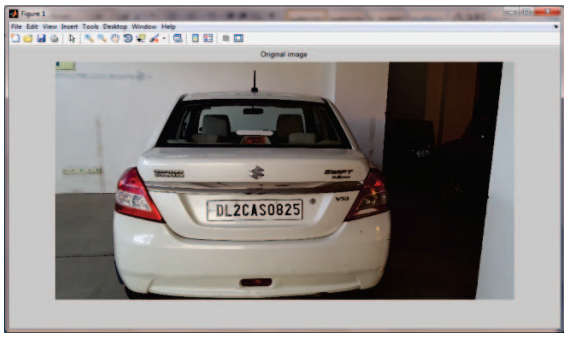

Fig. 2. Original image.

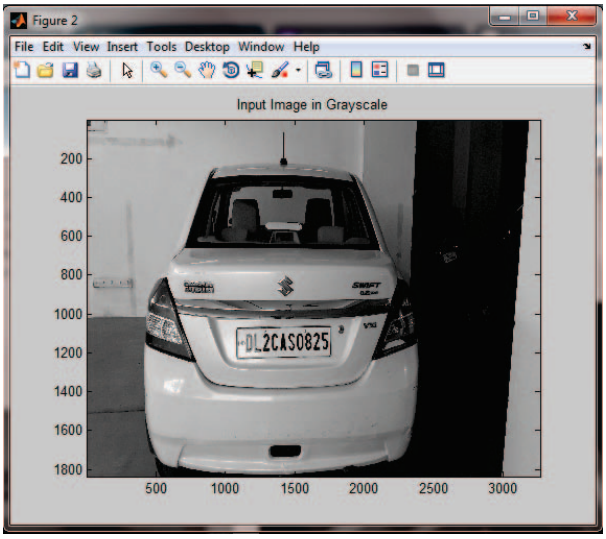

Fig. 3. RGB to gray.

III. NPR Implementation Using MATLAB in Real-Time

The process of NPR implementation using MATLAB is given below:

A. Input Image

In the proposed system, High resolution digital camera or an android-based device, is used for acquiring an image. The input image is 350×200 or 3500×2000 pixels (see Fig. 2).

B. Extraction of Number Plate Region

The images of vehicles captured by a camera were read/given to the system as an input. Colour image (RGB) is converted to gray scale image, in order to facilitate the plate extraction and increase the processing speed. Noise is removed by median filtering from gray scale image (see Figs. 3 and 4).

The basic step in recognition of vehicle number plate is to detect the plate size. In general number plates are in rectangular shape. Morphological operations are used to detect the region of interest and highlight regions with high edge magnitude and high edge variance. Morphological operations aim to remove unrelated objects in the image. Dilation and

Fig. 4. Median filtering.

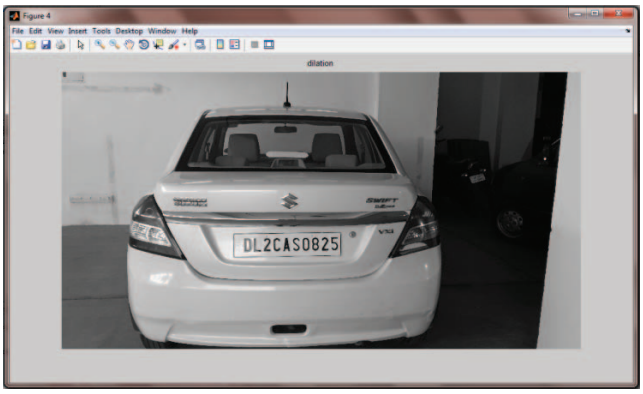

Fig. 5. Dilation.

Fig. 6. Eroded image.

erosion are used to extract number plate areas from the entire image (see Figs. 5 and 6).

The binary gradient mask shows high contrast lines in the image. These lines do not quite delineate the outline of the object of interest. Compared to the original image, gaps in the lines are observed that surrounds the object in the gradient mask. These linear gap disappears if the binary image is dilated using linear structuring elements.

Structuring element is represented as matrices, which is a characteristic of certain structure and features to measure the shape of an image which is used to carry out other image processing operations (see Figs. 7).

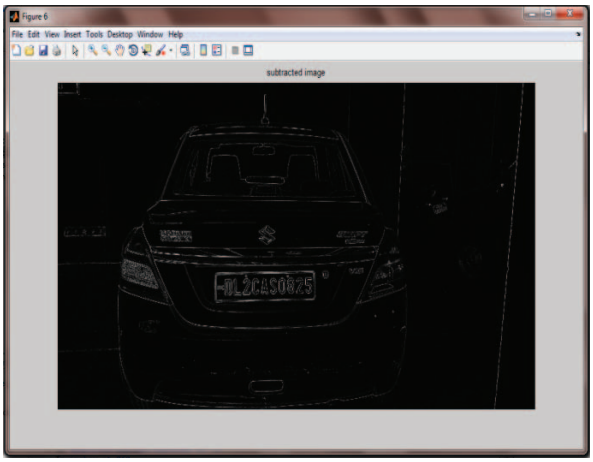

Fig. 7. Edge detection.

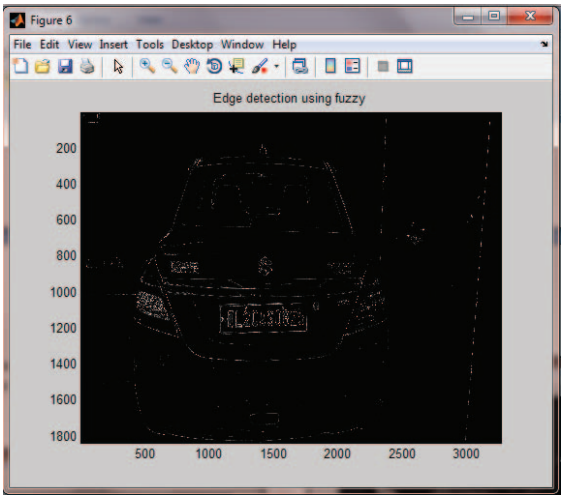

Fig. 8. Fuzzy filtered image.

C. Image Edge Detection using Fuzzy Logic

Fuzzy logic approach for image processing allows you to process gray scale image using the two dimensional default fuzzy transformation with input image matrix as a source. Then, the result is combined with two one-dimensional fuzzy transformations, one by rows and the other by column.

Fuzzy logic edge detection algorithm is used to obtain image gradient along x-axis and y-axis (see Figs. 8 and 9).

D. Image Feature Extraction and Template Matching

MATLAB toolbox provides 'imfill' function that fills holes in the binarized image. The dilated gradient mask shows the outline of the cell quite neatly, but there are still holes in the interior of the cell. The set of background pixels are known as hole that have not removed by filling the background from the edge of the image. Fig. 10 shows after removal of lower than 100 connected pixels. By filling holes the image of the captured vehicle is shown in Fig. 10 (see Fig. 11).

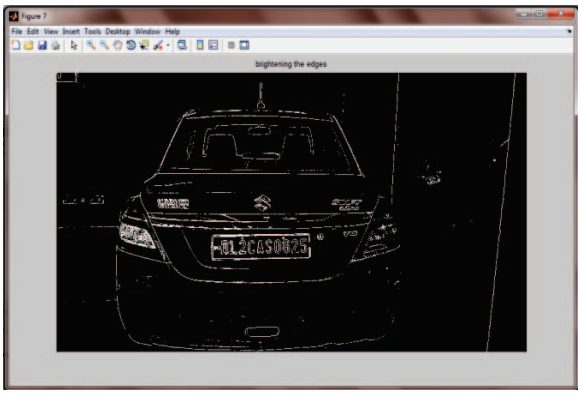

Fig. 9. Brightening the edges.

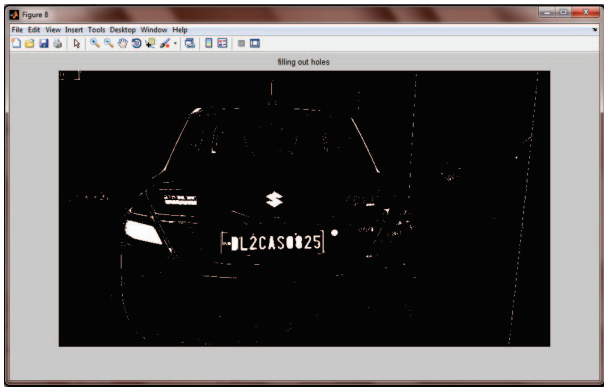

Fig. 10. Filling the holes

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Fig. 11. Template matching.

IMAGES	*MSE*	*PSNR*	*SSIM*
image1	*184.05*	*25.52*	*0.232*
image2	*188.65*	*25.41*	*0.224*

Fig. 12. Noise analysis.

IV. Experimental Results, Reliability Analysis and Discussion

The final result of our project is shown in Fig. 12.

Number plate recognition has been successfully implemented as the algorithm successfully detects the number plate region from the image which consists of vehicle number & then character segmentation, recognition [5] (see Table I).

TABLE I
Test Result of Vehicle Number Plate Detection Using MATLAB.

Algorithm	Images sampled	Accuracy of result (%)
Extraction of number plate	50	90.18%
Character recognition	50	79.30%

TABLE II
Noise Types and Their Effect on Image.

Types of noise	MSE	PSNR	SSIM
Gaussian	184.05	25.52	0.232
Salt & Pepper	1061.09	17.91	0.165
Poisson	109.23	27.78	0.405
Speckle	808.19	19.09	0.273

Various channel noises have been incorporated and robustness of the algorithm has been evaluated for standard noises: Gaussian, salt and pepper and rotation of image.

We have applied our algorithm on 50 images and found that it has successfully recognized them. We have recorded the database of different sized images of .jpg format.

The simulation results shows that the system can detect and recognize the vehicle using license plate against different lightening conditions and can be implemented on the entrance of a highly restricted areas.

Robustness of the algorithm has been tested by incorporation of channel noise elements as shown in images and mentioned before. The images hence have been exposed to noise and thereafter compared for loss of information and overall structure. Comparison methodologies used are MSE and PSNR values and Structured Similarity Index (SSIM) [6], of an image before and after exposure to channel noise. The accuracy of results thus obtained are reported in Table II.

Rotation of image: see Figs. 13, 14 and 15.

Noise filled images and their respective outputs after applying the algorithm: see Figs. 16, 17, 18, 19, 20 and 21.

V. Conclusion

We have successfully implemented number plate recognition. In this system, an application software is designed for the detection of number plate of vehicles using their number plate. At first plate location is extracted using morphological operation then separated the plate characters individually by segmentation. Finally template matching is applied with the use of correlation for recognition of plate characters. Some of possible difficulties: Broken number plate, Blurry images, Number plate not within the legal specification, Low resolution of the characters, Poor maintenance of the vehicle plate.

Similarity between certain characters, namely, O and D; 5 and S; 8 and B, E; O and 0, some show discrepancies in detection algorithm used.

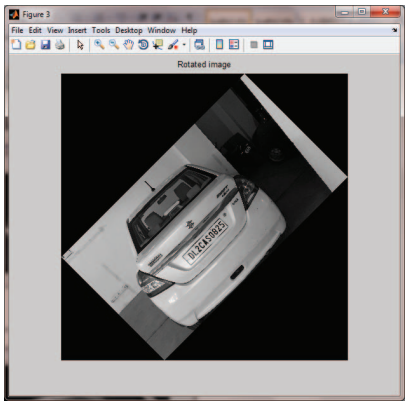

Fig. 13. 30 degree.

Fig. 14. 90 degree.

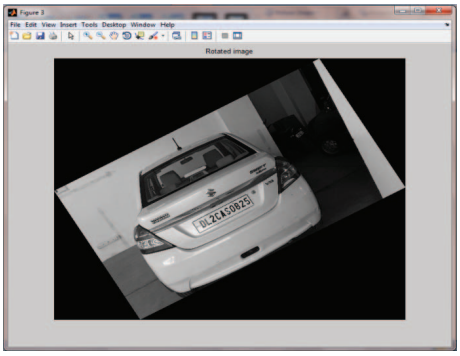

Fig. 15. 45 degree.

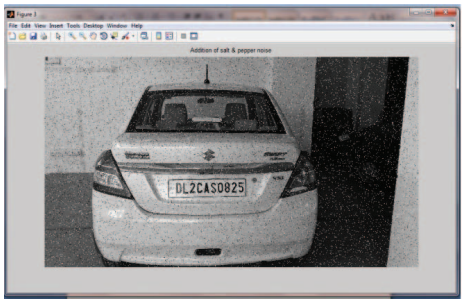

Fig. 16. Addition of Salt & Pepper noise.

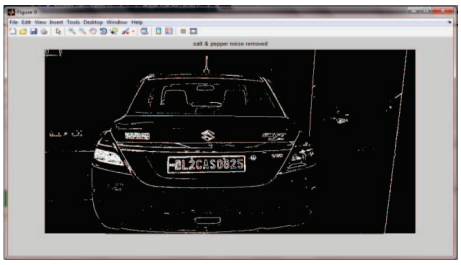

Fig. 17. Removal of Salt & Pepper noise.

Fig. 18. Addition of Poisson noise.

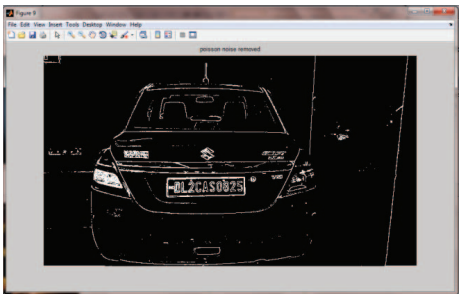

Fig. 19. Removal of Poisson noise.

Fig. 20. Addition of Speckle noise.

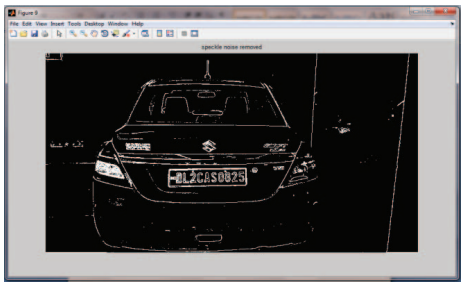

Fig. 21. Removal of Speckle noise.

Overall, we have successfully tested and implemented a real time, remotely controlled MATLAB based vehicle license plate recognition system with good accuracy. Further improvements and pathways include designing of a more robust system with testing of effect of various noise and filters on the vehicle's images, vector subspace modeling, manifold analysis, graph embedding, tensor modeling, etc. Also for feature designing, some attempts have been taken to model the spatial or spatial-temporal contexts for boosting visual classification, e.g., proximity distribution kernels and Markov stationary features. However these attempts are still limited mainly for 2nd order contexts and in unsupervised ways. The exploration of higher-order, supervised/semi-supervised and discriminative context modeling is desirable [7], [8].

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