Fully Automated License Plate Recognition

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Abstract

The ability to acquire license plate information in ASCII text format opens up many diverse and utilitarian applications. License plate recognition (LPR) is a key technique to many automated systems such as road traffic monitoring, automated payment of tolls on high ways or bridges, security access, and parking lots access control. Difficulties result from illumination variance, noise, complex and dirty background. In this paper, an automated license plate recognition system is proposed based on image processing, feature extraction and neural networks. This system utilizes colour based license plate localisation for finding and isolating the plate on the picture, which further goes through multiple levels of image pre-processing before final stage of character segmentation and neural network based recognition. Back-propagation neural network (BPNN) is selected as a powerful tool to perform the recognition process.

Problem Definition

Automatic recognition of license plate is an essential stage in intelligent traffic system, automated traffic management and law enforcement. Real time LPR plays a major role in automatic monitoring of traffic rules and maintaining law enforcement on public roads. The automatic identification of vehicles by the contents of their license plates is important in private transport applications. License plate recognition is a complex problem. The steps involved in recognition of a license plate can be categorised in brief into image acquisition, candidate region extraction, segmentation, and recognition. Process starts with image acquisition. This can be done using high resolution CCD colour cameras with fast shutter speeds, which will enable the LPR to perform from greater distance and on fast moving vehicles or a CMOS based low resolution camera that can perform well in restricted situations like an automated parking lot where images will be taken from close proximities and in good lighting conditions. Next task is finding and isolating the plate on the picture. Success of further stages solely lies on its result. The task is compounded due to variation in illumination, noise, motion blur and complicated background. Localisation is achieved on the basis of colour and dimension. Based on plate localisation information the image is cropped and sent to multiple stages of image pre-processing which removes noise, increases contrast and convert the image to binary which assist individual character segmentation. These segmented characters are then resized into a two dimensional grid of 15X10 size. Information thus obtained is fed to a back propagation neural network with 150 neurons (one for each grid element) in input layer, 1 hidden layer with 40 neurons and finally the output layer with 36 neurons, with each neuron corresponds to a number from 0 to 9 or character from A to Z. The neuron which corresponds to input data fires with highest weight.

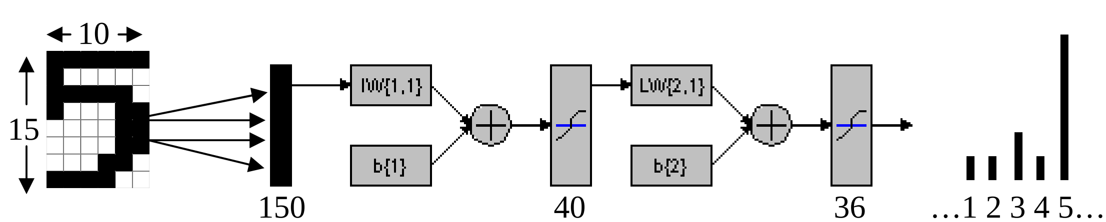


Figure1. Block diagram of BPNN based character recognition

Details about the Problem

Image acquisition

This is the first phase in the LPR system. The task of image acquisition can be achieved in three ways, selection of which depends on nature of application and economic consideration.

- Using a high resolution CCD based colour camera with fast shutter speed. This is required in real time LPR of fast moving traffic. CCD sensor ensures good images even in low light condition. High resolution and fast shutter speed make sure that the image can be further processed even when it is taken from a large distance.
- Using a low resolution CMOS based colour camera which are considerably cheaper as compared to other cameras, but will perform satisfactorily in controlled environments like parking lots and toll gates where pictures will be taken from very close proximity and in good lighting condition.
- Infra-red cameras will perform in total darkness. This could be useful in specific circumstances. As infrared (IR) spectrum lies below visible spectrum, the image thus obtained will be an intensity image and will lack colours. The system described in this paper works on colour based plate localisation and will fail to work with this kind of camera.

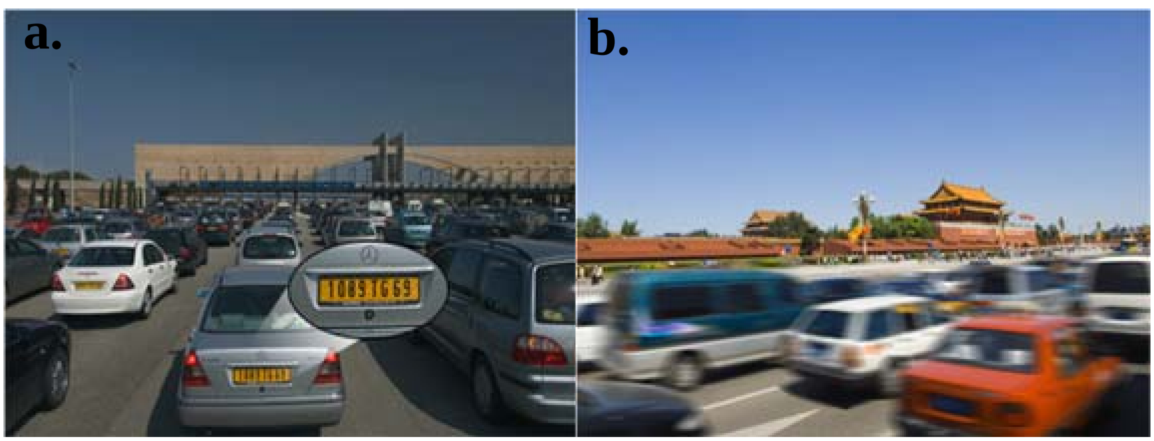


Figure2. (a) Image captured with high resolution CCD camera with high shutter speed. Note that the number plate is recognizable even from a large distance. (b) Image taken with a slow shutter speed camera. Number plates are unrecognizable due to motion blur.

Plate localisation

The problem of locating number plate is one of the most difficult as well as important one as accuracy of subsequent stages depends on it. This paper exploits the fact that license plates have yellow background and black text (this is applicable to commercial vehicles in India) and have specific dimensional characteristics of a rectangle. Problem arises because a colour can appear very different under different lighting conditions. To overcome this problem the original image is first processed to reduce number of colours to around 50 and then colour space is changed from RGB to HSV. HSV is a nonlinear transformation of the RGB colour space and is capable of representing colour in hue (H), saturation (S) and value or brightness (V) form. So even with varying lighting condition brightness (V) can vary over a wide range but hue (H) and saturation (S) will remain almost same. Based on these constraints regions are selected. These regions are processed using standard image processing functions like dilate, smooth, erode and fill which increases reliability of correct plate localisation. The region passes through a qualifier and if it qualifies as a license plate then its bounding box coordinates are used to crop the original image and get the license plate only. The qualifier checks for following conditions

- Area of the region is not less than a specified threshold value.
- Length to breadth or aspect ratio is within a specific limit. This limit should lie within 10:1 and 2:1. Rules can be enforced by the government to ensure this.

. Figure3. (a) Original image. (b) Image after colour reduction (c) After region qualifier (d) Final cropped image.

Normalisation and contrast enhancement

Before image is passed on to character segmentation stage it must be pre-processed to enhance contrast and make it suitable for further stages. First the image is transformed to greyscale which is followed by application of 3x3 median filter to remove noise. At this stage an edge enhancement filter may also be applied to sharpen edges to aid segmentation. Based on the image, threshold value is computed and image is converted to binary.

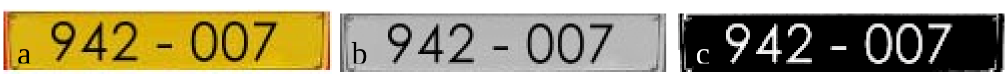


Figure4. (a)Original image after localisation stage (b) Gray scale conversion, median filtering, and edge enhancement. (c) Thresholding and binary conversion

Character segmentation

The binary image thus obtained is then segmented into regions based on intensity value. Each region could be a potential character block. To test for this each region is again passed through a character qualifier stage. This stage checks if,

- Area of bounding box is within a threshold value. This value is decided by area of number plate itself.
- Length to breadth ratio must lie within a specified limit.

Based on these conditions characters are segmented and resized into 15X10 sized grids which will be then fed to neural network.

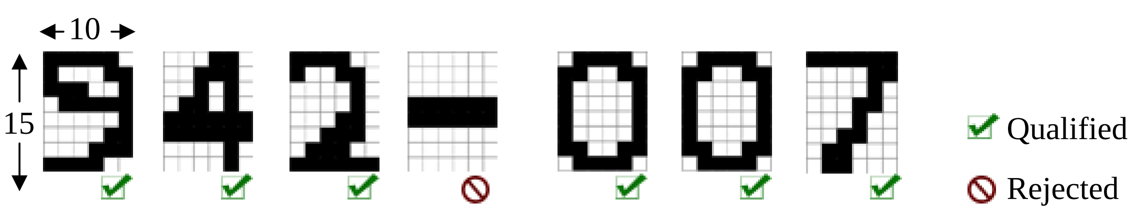
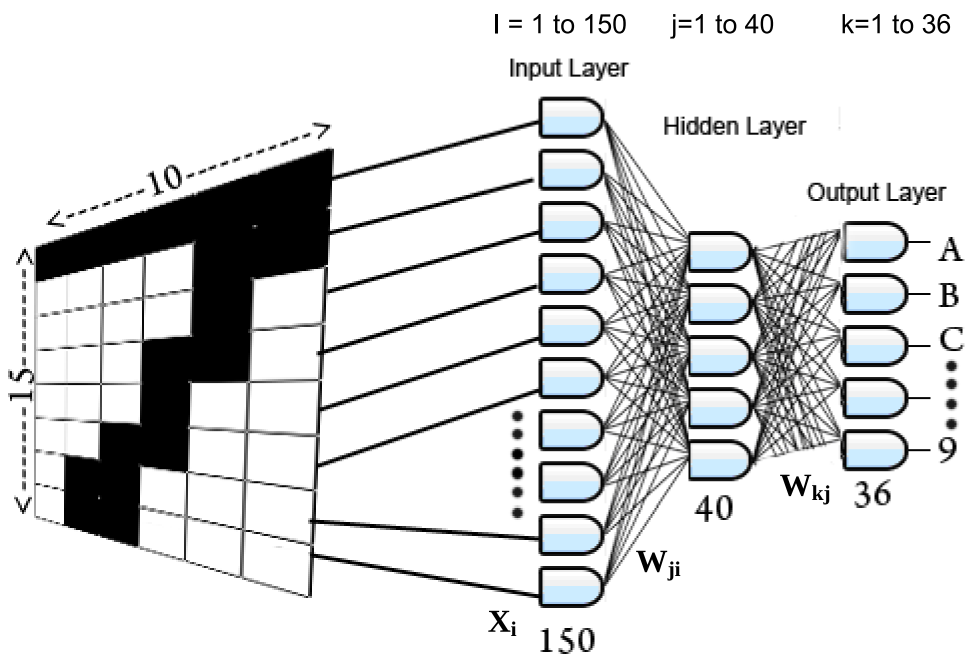


Figure 5.Output after segmentation stage.

Character recognition

This is the final stage in LPR system. Although many complex algorithms do exist, BPNN based recognition outperforms all because of its simplicity and reliability. It must be ensured that the network generalizes properly so that it performs well on different data sets. One of the problems that occur during neural network training is called overfitting. The error on the training set is driven to a very small value, but when new data is presented to the network the error is large. The network has memorized the training examples, but it has not learned to generalize to new situations. To avoid this problem large amount of data is gathered, and is divided into three subsets. The first subset is the training set, which is used for computing the gradient and updating the network weights and biases. The second subset is the validation set. The error on the validation set is monitored during the training process. The validation error normally decreases during the initial phase of training, as does the training set error. However, when the network begins to overfit the data, the error on the validation set typically begins to rise. When the validation error increases for a specified number of iterations, the training is stopped, and the weights and biases at the minimum of the validation error are returned. Third set is the test set and tests are performed on the network using them. This method helps arrive at an optimal network that would perform with greater accuracy in diverse situations.



$$net_j = [W_{ji}][X_i]$$

$$net_k = [W_{kj}][net_j]$$

$\mathbf{X_i}$ = Input vector as obtained from segmented character.
$\mathbf{W_{ji}}$ = synaptic weight between $\mathbf{j_{th}}$ hidden node and $\mathbf{i_{th}}$ node of input layer.
$\mathbf{W_{kj}}$ = synaptic weight between $\mathbf{k_{th}}$ output layer and $\mathbf{j_{th}}$ hidden layer.
net_k = input of activation function at output layer.
$netj$ = input of activation function at hidden layer.

Figure6. Block diagram of neural network employed.

From figure6 it is clear that the operation of a trained neuron is simple matrix operation. Therefore even if the process of training can take large amount of time but the process of computing results on a trained network is completed in very small time. This makes it possible to use this system for real time LPR. Image processing itself is a resource intensive task and this must be taken into consideration while designing a realtime LPR system. Nonetheless the neural network itself will never become a hindrance in realtime operation.

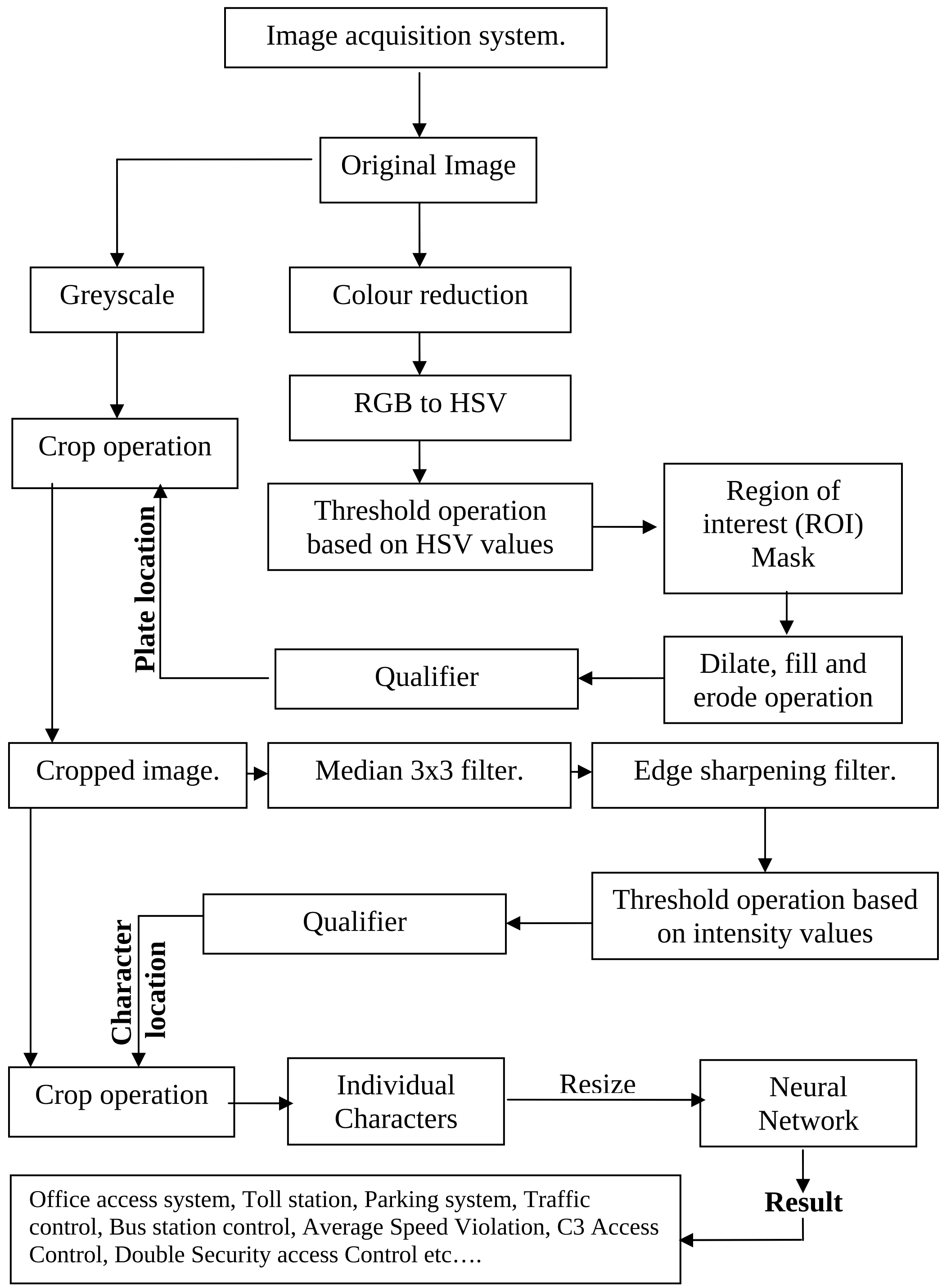


Figure7. Stages of operation

Computer realization

The system is realized on a computer which allows studying its response to different sets of input and helps better understand/fine tune its working. Programming is done in Matlab® using standard Image Processing Toolbox and Neural Network Toolbox. Images are gathered from internet and are used to train, validate and test the neural network. Based on performance certain parameters are tweaked. Finally the program is run on a completely new set of data and performance is observed. Please note in this implementation neurons are trained to recognise numbers only.

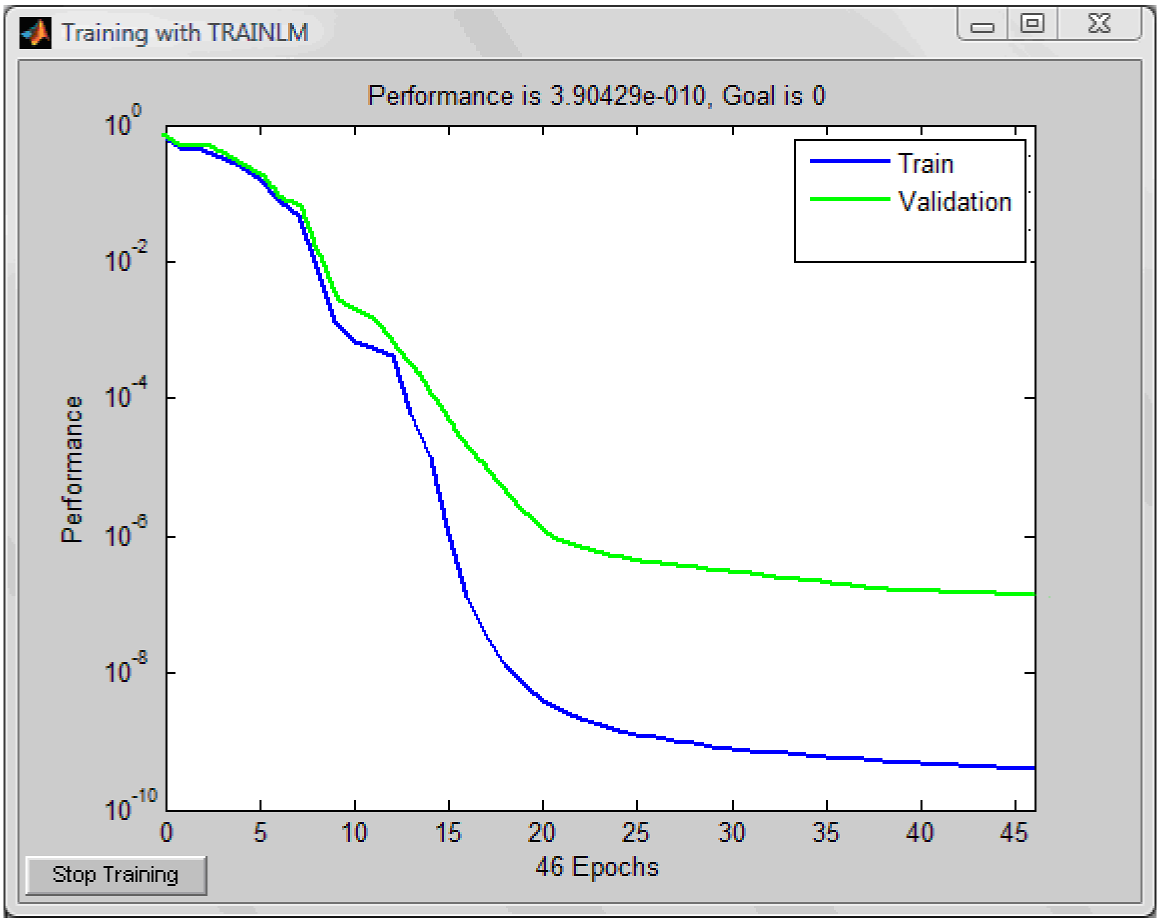


Figure13. Result of training after 46 epochs in neural network toolbox. Note how validation curve is deviating with increasing number of epochs.

Results and summary

The performance of the system was brilliant. With just 30 sets of data used for training, testing and validation the system gave a hit ratio of 96% (24 correct LPR on 25 set of data) on completely new data. It performed with 100% accuracy on set that was used for training. Unless and until font used in test data and training data was very different, system performed satisfactorily even on images with varied illumination and background complexity. But with change in font results were not good enough. Performance also decreased with increasing epochs for training cycle. This was because with limited data sets available the network overfitted training data and performed poorly on new data set.

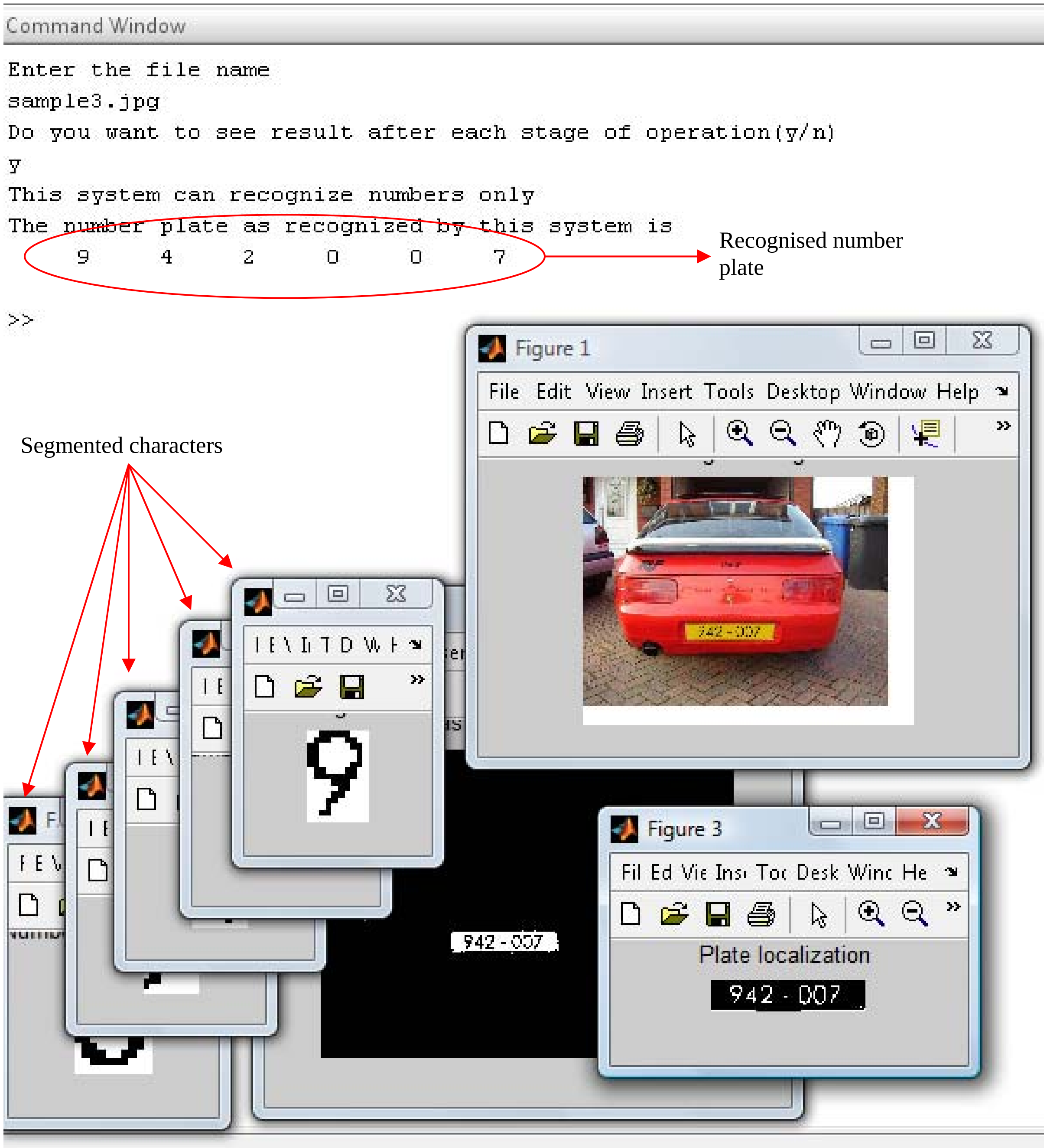


Figure14. Output of the program for a given image.

Future directions

The techniques presented in this paper have certain limitations and shortcomings. Owing to its dependence on colour based plate localisation, the system will fail to work on greyscale images and images captured by infrared cameras. Also this dependence forces number plates to comply with specific colour schemas. Recognition rates will fall if no standard font is specified for number plates. These rules can be enforced by the Government. Better localisation techniques have to develop that can localise plates in diverse situations and feed them to smarter recognition systems that could recognise wide variety of fonts and plate styles. It is clear that some problems which are trivial for a human being can be very difficult for a computer.

Attachments

All files are zipped into a single file “sourcecode.zip” and attached with this pdf file. This zip file includes following files…

- automatedrecog.m : Matlab® source file for LPR system.
- network.mat : Matlab neural toolbox file with information on weights and network parameters used by automatedrecog.m to perform recognition.
- Sample1.jpg to sample9.jpg : Sample images for the program.

References

- US Patent – 6,473,517; Character segmentation method for vehicle license plate recognition; Inventor: Jenn-Kwei Tyan, Claus Neubauer; Assignee: Siemens Corporate Research, Inc. Issue date: Oct 29, 2002
- License plate localization and recognition in camera pictures; Halina Kwaśnicka and Bartosz Wawrzyniak, faculty division of computer science, Wrocław University of Technology,
- Technical case studies and articles on neural networks, pattern recognition and vision systems at www.sciencedirect.com, http://en.wikipedia.org and http://visl.technion.ac.il