Project Title: Implementation of Automatic Number Plate Recognition (ANPR) using Image Processing and Neural Network for Vehicle Security

Name of the Guide/Co-Guide: Prof. Maruti B. Zalte, Associate Professor, KJSCE, Mumbai.

Students: Rajdeep Adak (rajdeep.adak@somaiya.edu), 3rd Year Undergraduate, KJSCE, Mumbai
Abhishek Kumbhar (abhishek.kumbhar@somaiya.edu), 3rd Year Undergraduate, KJSCE, Mumbai
Rajas Pathare (rajas.pathare@somaiya.edu), 3rd Year Undergraduate, KJSCE Mumbai
Sagar Gowda (sagar.gowda@somaiya.edu), 3rd Year Undergraduate, KJSCE Mumbai

Abstract

Automatic Number Plate Recognition (ANPR) is a technique designed to read vehicle number plates without human intervention using high speed image capture with supporting illumination, detection of characters within the images provided, verification of the character sequences as being those from a vehicle numberplate, character recognition to convert image to text; so ending up with a set of metadata that identifies an image containing a vehicle numberplate and the associated decoded text of that plate. Most members of the public will be aware that ANPR is used by police forces to track criminal behavior on road. However, ANPR is used in a variety of other ways to support the security and safety of the public as well as supports the way we interact with transportation and vehicle based infrastructure. This documentation presents implementation of a Deep Learning based ANPR technique. We test the program based on our analysis on real-life traffic videos and store Numberplate text and image into a directory. Any number plate can be searched from this directory as the file name is the predicted text from the implemented ANPR algorithm. Results demonstrate the accuracy of the ANPR technique on various scenarios. A performance review describes robustness, utility, cost, complexity and ease of deployment. We have made our datasets of images and videos, theoretical analysis, results of experiments, program architecture and code available for further exploration and contribution.

Keywords

Automatic Number Plate Recognition (ANPR), Contour Detection, Segmentation, Convolutional Neural Networks (CNN), YOLO, Darknet, CUDA, Bilateral Filter, Canny Edge Detection, Blob Removal, Adaptive Thresholding, Otsu's Thresholding.

Concepts

To achieve only characters from an image/video of an entire environment requires implementing the concepts of Edge Detection, Pattern Recognition, Region of Interest Detection, Image Filtering, Contour Detection, Contour Segmentation, and Convolutional Neural Networks. The above concepts are briefly explained below and have been applied methodically to obtain optimal results.

Edge Detection: Edge detection is an image processing technique for finding the boundaries of objects within images. It works by detecting discontinuities in brightness.

Pattern Recognition: Pattern recognition is the ability to detect arrangements of characteristics or data that yield information about a given system or data set. In a technological context, a pattern might be recurring sequences of data over time that can be used to predict trends, particular configurations of features in images that identify objects, frequent combinations of words and phrases, or particular clusters of behavior on a network etc.

Region of Interest (ROI): A region of interest (often abbreviated ROI), are samples within a data set identified for a particular purpose. The concept of a ROI is commonly used in many application areas. In our case, the 1st ROI is the numberplate and 2nd ROI is the characters (A-Z or a-z) and numbers (0-9) in the numberplate.

Image Filtering: To remove noise and various unwanted shapes and impurities from the image a number of pre-processing algorithms have been applied. These allow elimination of fake characters which can be wrongly detected.

Contour Detection: Contours detection is a process can be explained simply as a curve joining all the continuous points (along with the boundary), having same color or intensity. The contours are a useful tool for shape analysis and object detection and recognition. We utilize this to find characters and numbers as they are continuous figures (this however depends upon the chosen font as some fonts may not keep all characters and numbers as continuous figures).

Contour Segmentation: Segmentation is a section of image processing for the separation or segregation of information from the required target region of the image. Once contours are detected they can easily be separated from the rest of the image.

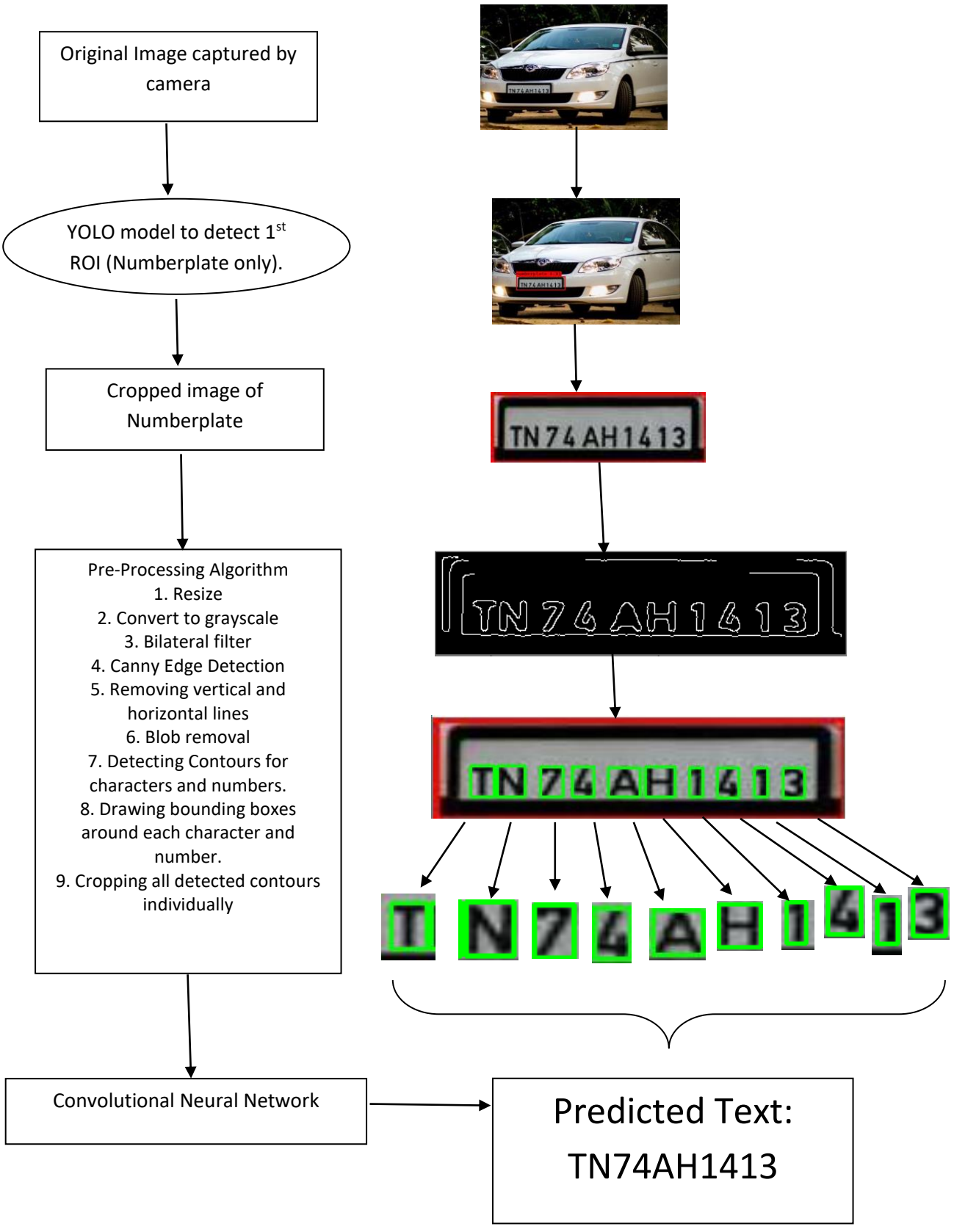
Convolutional Neural Networks: A Convolutional Neural Network (ConvNet/CNN**)** is a Deep Learning algorithm which can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms. While in primitive methods filters are hand-engineered, with enough training, ConvNets have the ability to learn these filters/characteristics.

Approach

As previously mentioned he 1st region of interest (ROI) is the numberplate itself. To segregate the number plate from the rest of the image we utilize YOLO. YOLO which stands for 'You Only Look Once' is an Object Detection Algorithm. In comparison to recognition algorithms, a detection algorithm does not only predict class labels but detects locations of objects as well. So, it not only classifies the image into a category, but it can also detect multiple Objects within an image. This Algorithm doesn't depend on multiple Neural networks. It applies a single Neural network to the Full Image. This network divides the image into regions and predicts bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities. Our code for object detection will use weights trained from custom dataset of 'Number Plates' collected and labelled solely by the team using Darknet Yolo v3. Darknet is an open source neural network framework written in C and CUDA. It is fast, easy to install, and supports CPU and GPU computation. The weights used in Darknet Yolo v3 are converted into '.h5' file, weights used by Keras. An h5 file is a data file saved in the Hierarchical Data Format (HDF). This converted weights or Keras Model is then used to predict the bounding boxes and class probabilities using keras library. Once the number plate is detected, it is cropped from the image and is passed on to detect the 2nd Region of Interest (ROI) i.e. individual characters. Various Image Processing algorithms are used to perform filtering of content which isn't a character or a number. The resultant image consists figures which include all characters and numbers present in the numberplate along with those which are probable characters and number plates.

Methodology

The ANPR program architecture is mentioned below:



Results

After training the CNN the program was tested on a large set of images. The overall accuracy obtained is 83 %. The environmental factors we have aimed to mitigate are:

1. Over Exposed Images.
2. Blurred Images.
3. Images with angular perspective.
4. Randomly chosen custom font.
5. Rotated Images.
6. Shaded Images.
7. Straight Image.
8. Image with a colored Numberplate background.
9. Multiline Image.

The following table consists of 10 images each of which have an environmental factor. Their character accuracy, predicted number plate label and processing time have been shown.

Sr. No.	Environmental Factor	Predicted label	True label	character accuracy	proc time(sec)
1	Angular perspective	DL3CBD5092	DL3CBD5092	100%	0.308
2	Blurred	73H12AF5032	MH12AF5032	90%	0.197
3	Custom Font 1	KL59T997	KL59T997	100%	0.44
4	Custom Font 2	HR658795	HR16S8179	60%	0.346
5	MultiLine	MH14GN9239	EFN9239	50%	0.4
6	Over exposed	MH02EP6969	MH02EP6969	100%	0.464
7	Rotated	AP05BL6339	AP05BL6339	100%	0.19
8	Shaded	GJH06C122	JH06C1122	77%	0.59
9	Straight front	MH20DV2362	MH20DV2362	100%	0.75
10	Coloured background	DL1RTA2179	DL1RTA2179	100%	0.3

Images chosen for this purpose have been shown below:

Angular perspective

Blurred

Custom Font

Custom font

Multiline

Over Exposed

Rotated

Shaded

Straight front

Coloured Background Numberplate

Observations

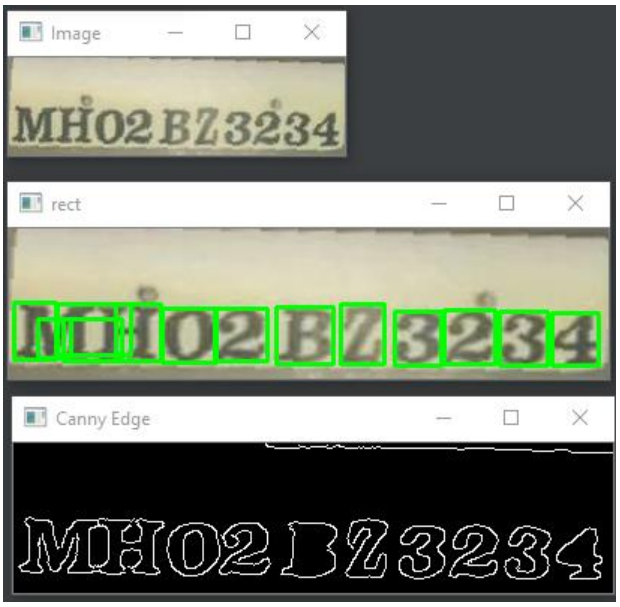
Average accuracy obtained on a set of 10 images with environmental factors = 87.7%
Average accuracy on a set of 10 straight front images (with no environmental factors) = **95 %**
Difference in accuracy caused by presence of environmental factors = 95% – 87.7% = **7.3 %**
Difference in overall accuracy = 95% - 83% = **12%**
Average processing time = **0.3985 seconds**.

Inference

From the observations it is inferred that on straight front images the ANPR program works with an accuracy of up to 95%. Due to presence of environmental factors a deficit of 7.3% - 12% is observed. Hence the ANPR program will produce unsatisfactory results up to 12 % of all cases. Upon analysis of the reason behind 12 % inaccuracy we have deduced 2 major causes:

1. **Improper contours produced by the pre-processing steps**.

The contour detection works on the basis of finding continuous pixels of same intensity or color. Certain environmental factors affect the contour detection as characters or numbers may not be distinctly segregated. This can appear in case when the gap between two characters is too small, presence of a mounting nail, blurred image, shadow causing lowering of intensity etc. Upon changing the parameters utilized in the bilateral filter and canny edge detection functions we have observed a better result. However the program is a generalized code and hence only the meticulously chosen parameter values have been written. Besides Canny edge detection algorithm, Adaptive thresholding algorithm and Otsu's thresholding have also shown good results. Some images with altered parameter values have been shown below that mitigate the environmental factor affecting the accuracy.

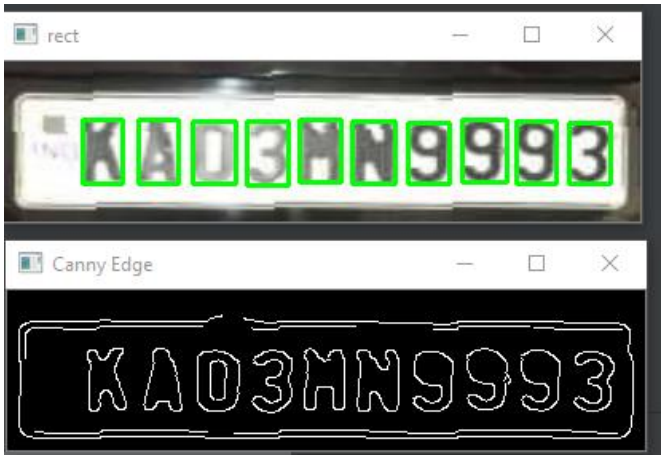


Here the letters M and H appear as continuous contours in output of pre-processing steps. Hence the character is incorrectly determined

The numbers 5 and 0 have a dot in between which seems to be a mounting nail. The contour detection fails as they are detected as a single character but out of the bounds of the aspect ratio of a single character. Hence not highlighted.

2. Ambiguous characters and numbers improperly classified.

Certain characters and numbers such as the letter G and C, number 6 can be wrongly detected as they have similar feature maps. It depends on how well the CNN is trained to efficiently distinguish between such ambiguous characters.



Here even though all the characters are well separated and detected effectively by the pre-processing algorithm the output is however = KA03HN9993. The letter M and H have an ambiguity and it is clearly observed in the image.

Other factors that can affect the accuracy of the algorithm are hardware inadequacies such as low shutter speed, low fps, low resolution, improperly positioned camera, rain, polluted air, dirt etc.

Conclusion

The design ANPR program produces excellent accuracy for straight front images and is hindered up to 12 % due to environmental factors. The same hindrance is observed up to 42 % without the right pre-processing. Hence we have achieved the objective of reducing the effect of environmental factors on an ANPR system. The ANPR system has been tested in multiple scenarios and is concluded to be sufficiently reliable.

Cost & Utility

1. Road and traffic security. To report over-speeding vehicles, absconding vehicles.
2. Law enforcement. For example: Border patrol, Road crime investigation, hit and run cases.
3. Parking Automation. Automatic parking saves time and ensures efficient management of parking space.
4. Access Control. Limiting access to certain areas where the road jamming and congestion are strictly prohibited. For example: Airports, government offices etc.
5. Journey time measurement.
6. ANPR Databases. Advanced ANPR technology keeps a database of detected car number plates. They have been very helpful in location tracking and activity history detailing during multiple crime investigations.
7. Motorway Road Tolling. This allows reduction of manual labor during tolling.

In India there are 210,000,000 vehicles with 250,000 traffic cameras. However, not all of them are equipped with ANPR technology. There have been some news of local police ordering installation of ANPR cameras but the utility of ANPR is yet to reach satisfactory stages.

Project Links

1. Live working of the ANPR program:
https://drive.google.com/file/d/16FtmB4nf72bSE5sHBBZYtXO7vxrqaX_5/view

2. Project link. The code, datasets, images and videos are available on github. We welcome recommendations and contributions to the project:
https://github.com/rajdeepadak/ANPR-using-Image-Processing-and-Deep-Learning

References

https://en.wikipedia.org/wiki/Automatic_number-plate_recognition
http://www.anpr.net/anpr_09/anpr_applicationareas.html
https://www.anprcameras.com/about-us/understanding-anpr/
https://3wnews.org/uncategorised/836326/automatic-license-plate-recognition-alpr-software-product-sale-skyrockets-amid-unprecedented-demand-spurred-by-raging-covid-19-outbreak/
https://platerecognizer.com/blog/anpr-for-india/
http://investigations.nbcnews.com/_news/2013/07/19/19548772-license-plate-data-not-just-for-cops-private-companies-are-tracking-your-car?lite