Sri Lanka Institute of Information Technology

Faculty of Engineering

Research Project (EC3800)

Final Report

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Abstract

This research evaluates the performance of a vehicle number plate recognition system using Normalized Cross-Correlation (NCC) and Phase Correlation. The system employs image processing techniques to preprocess images, isolate number plate regions, and segment characters. A dataset of 70 number plates was used, with 32 plates (215 characters) processed for evaluation. Results show that NCC achieved an accuracy of 85.58%, significantly outperforming Phase Correlation at 51.63%. These findings highlight NCC's effectiveness for real-world number plate recognition.

Introduction

Vehicle number plate recognition (VNPR) systems have become indispensable in modern traffic management, surveillance, and law enforcement. By automatically identifying vehicle number plates, these systems streamline various processes such as toll collection, traffic monitoring, access control in restricted areas, and the detection of stolen or unauthorized vehicles. Beyond these applications, VNPR systems also play a critical role in urban planning and smart city initiatives, offering valuable data for traffic flow optimization and policy-making.

This research evaluates the performance of two template matching methods which are normalized cross-correlation (NCC) and phase correlation for character recognition in Sri Lankan number plates. The unique variations in size, font, and aspect ratios of these plates necessitate robust and adaptive algorithms. The process begins with a preprocessing algorithm that isolates the number plate region through grayscale conversion, edge detection, morphological operations, and region validation based on aspect ratios. Detected regions are segmented into individual characters, which are resized and matched against predefined templates using NCC and phase correlation techniques.

From 50 tested number plates, 32 plates with successfully detected regions (215 characters) were analyzed. Results revealed that NCC achieved a superior accuracy of 85.58%, while phase correlation achieved 51.63%. These findings emphasize the importance of selecting effective template matching techniques to enhance the accuracy and reliability of vehicle number plate recognition systems.

Methodology

This research employs a structured approach for automated recognition of Sri Lankan vehicle number plates, utilizing image processing techniques and template matching methods. The methodology involves several stages, from preprocessing the image to recognizing individual characters on the number plate using correlation-based methods: Normalized Cross-Correlation (NCC) and Phase Correlation. The following is a comprehensive breakdown of the methodology,

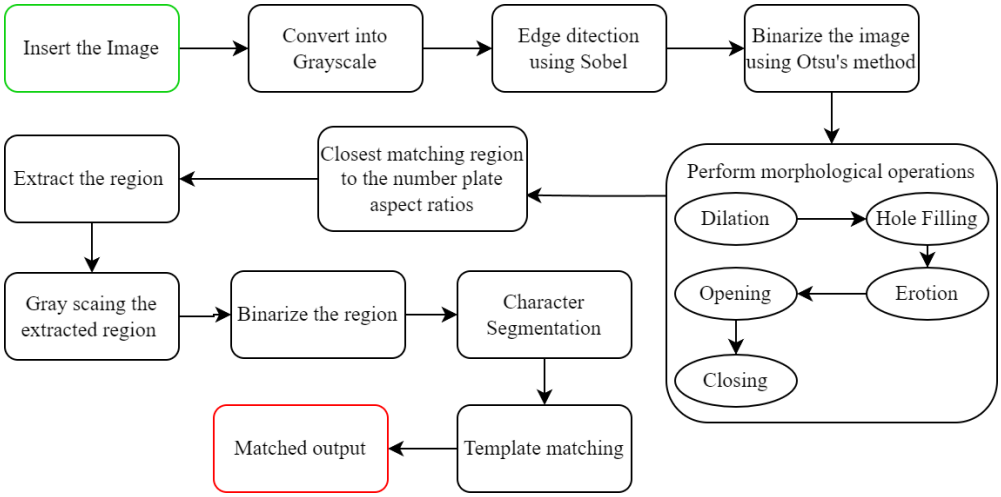

Figure 1: Flow chart of the process

1. Image processing

- The preprocessing stage enhances the input image for easier number plate detection. The color image is converted to grayscale to reduce complexity, focusing on intensity variations. Edge detection, using the Sobel operator, identifies boundaries to highlight the number plate region. The edge-detected image is then binarized using Otsu's method, separating foreground objects from the background. Morphological operations, including dilation and erosion, refine the binary image by filling gaps and removing noise. Advanced operations like opening and closing further clean the image, ensuring well-defined regions for analysis.

2. Region Detection and Segmentation

- After preprocessing, the system identifies potential number plate regions by analyzing the binary image. Connected components are evaluated based on their area, solidity, and bounding box properties. The largest regions are prioritized, with further filtering applied using aspect ratios of Sri Lankan number plate standards and solidity checks to retain only those closely matching the rectangular shape and dimensions of a number plate. Using this method a potential number plate region is recognized.

Table 1: Sri Lankan standard moto vehicle number plate sizes and aspect ratios

Category of Vehicles	Size of Plate	Aspect ratio
All vehicles except land vehicles and motorcycles / All vehicles	520 x 110 mm	4.73
All vehicles except land vehicles and motorcycles / All vehicles	280 x 200 mm	1.40
All vehicles except land vehicles and motorcycles	280 x 180 mm	1.56
Land Vehicles and Motorcycles	240 x 130 mm	1.33
Motorcycles	300 x 80 mm	3.75

3. **Character Segmentation**
    - **Character Binarization and Labeling**: The number plate region is binarized using adaptive thresholding, which helps separate the characters from the background. Connected components analysis is applied again to segment individual characters.
    - **Character Validation**: Each segmented character's width and height are analyzed, and only those characters whose dimensions fall within predefined thresholds are retained. This helps to filter out noise and irrelevant regions.
    - **Character Cropping and Resizing**: The valid characters are cropped from the binary image and resized to a uniform size which in this case is 70×70 pixels. Resizing ensures that all characters are processed at the same scale as the predefined templates.

4. **Template Matching**
    - **Normalized Cross Correlation**: NCC is used to measure the similarity between segmented characters and predefined templates based on pixel intensity patterns. For each character, NCC calculates scores by comparing intensity patterns with all templates, and the template with the highest score is selected as the best match.
    - **Phase Correlation**: This is a frequency-domain method, that matches segmented characters with templates by analyzing phase information using the Discrete Fourier Transform (DFT). The method calculates the cross-power spectrum of the character and template images, normalizing it to retain only phase information for robustness against noise and intensity variations. The spectrum is transformed back to the spatial domain using the Inverse Fourier Transform (IFFT), producing a correlation matrix. The template with the highest peak correlation score is identified as the best match, and this process is repeated for all segmented characters.

Results

he performance of the vehicle number plate recognition system was evaluated using a dataset of 50 number plates. Out of these, 32 number plates with successfully detected regions were analyzed, encompassing a total of 215 characters. The recognition process was conducted using two template matching techniques: Normalized Cross-Correlation (NCC) and Phase Correlation (PC).

First, the input image for the template matching was shown in the left most corner of Figure 02 below, the inputted image first goes through a pre-processing part in order to identify the number plate from the image and to segment letters. First it is turned to grayscale. Afterwards, the image goes through Sobel edge detection as shown in the right most image of Figure 02.

Figure 2: Original image, gray scaled image and Sobel edge detected image from left to right in order

After edge detection, the image goes through binarization and the Dilation, hole filling, Erosion followed by opening, closing and then to find the region of the number plate using number plate aspect ratios and solidity values. After finding the closest areas, they were marked as shown in the right most image in Figure 03

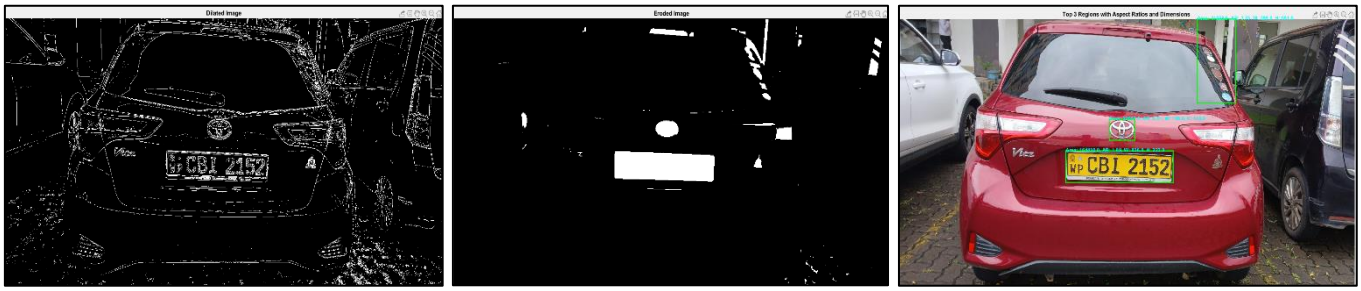

Figure 3: Dilation, Erosion and detected possible number plate regions from left to right

The detected number plate region goes through gray scaling, Binarizing and segmentation as shown in Figure 04. And after segmenting the smaller unnecessary characters, and distortions were filtered through as shown in the image on the right side of Figure 04.

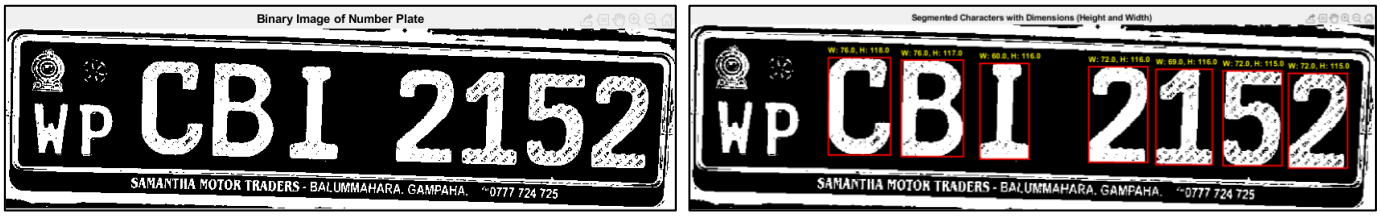

Figure 4: Binarized image, and the filtered characters based on the dimensions shown from left to right.

After segmenting the images, they were match with predefined templates using Normalized cross correlation or Phase correlation method.

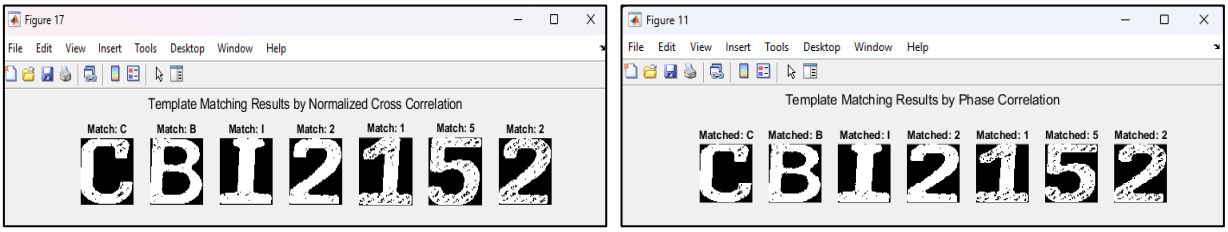

Figure 5: Template matched images using Normalized Cross Correlation and Phase Correlation.

Table 2: Identified amount of letters in the 32 number plates using NCC or PC.

Initial Letters	**A (7)**	**B (16)**	**C (24)**	**D (1)**	**E (3)**	**G (3)**	**H (1)**	**I (3)**	**K (8)**	**L (6)**	**M (4)**	**N (1)**	**Q (2)**	**R (1)**	**S (1)**	**U (3)**	**X (1)**	**Z (1)**	**Total (87)**
Identified by NCC	7	13	21	0	3	3	1	3	8	2	1	1	1	1	1	2	1	1	70
Identified by PC	3	10	18	0	2	2	0	1	3	3	1	1	0	0	1	1	1	1	48

Table 3: Identified amount of numbers in the 32 number plates using NCC or PC.

Initial Numbers	0 (15)	1 (14)	2 (8)	3 (16)	4 (15)	5 (14)	6 (12)	7 (12)	8 (13)	9 (9)	Total (128)
Identified by NCC	15	14	8	13	12	14	8	10	13	7	114
Identified by PC	10	12	6	2	8	5	5	5	7	3	63

Table 4: Total accuracy of NCC and PC template matching methods

Total amount Characters	Total Letters (87)	Total Numbers (128)	Total of Both (215)	Accuracy of Recognition $\left(\frac{\text{Succesfully Identified}}{215} \times 100\%\right)$
Identified by NCC	70	114	184	$\frac{184}{215} \times 100\% = 85.58\%$
Identified by PC	48	63	111	$\frac{111}{215} \times 100\% = 51.63\%$

- The results clearly demonstrate the superiority of Normalized Cross-Correlation (NCC) over Phase Correlation (PC) for vehicle number plate recognition. With an accuracy of 85.58%, NCC effectively handles the challenges posed by variations in font, size, and alignment, making it a more reliable choice for real-world applications compared to the lower accuracy of 51.63% achieved by PC.

Conclusion

This research demonstrates the effectiveness of template matching techniques, specifically Normalized Cross-Correlation (NCC) and Phase Correlation (PC), for vehicle number plate recognition in Sri Lanka. The results show that NCC outperforms PC with an accuracy of 85.58%, compared to 51.63% for PC. These findings emphasize the importance of selecting the right matching method to improve the accuracy and reliability of number plate recognition systems, especially for Sri Lankan plates with varying fonts and aspect ratios.

References

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