Automatic License Plate Recognition

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ABSTRACT:

Automatic license plate recognition using Image processing offer students a unique opportunity to gain hands-on experience in designing and optimizing the Embedded system. This typically involve working with industry professionals on actual projects, providing interns with valuable exposure to real-world challenges and best practices in the field of Embedded system.

During the project, participants are often tasked with designing using specialized software tools like MATLAB. In recent times, the number of vehicles on road has exponentially risen due to which traffic congestion and violations are a menace on roads. Automatic License Plate Recognition (ALPR) system can be used to automate the process of traffic management thereby easing out the flow of traffic and strengthening the access control systems.

In this paper, we compare the efficiency achieved by morphological processing and edge processing algorithms. A detailed analysis and optimization of neutral network parameters such as regularization parameter, number of hidden layer units and number of iterations is done. The system utilizes image processing techniques and machine learning algorithms running on MATLAB and Arduino to obtain the results with an efficiency of 97%. The system was tested on a set of static images as well as in a dynamic environment. The execution time of the system on a dynamic environment and the license plate of the vehicle can be identified as well.

In addition to technical skills, interns gain exposure to the latest industry trends and technologies, preparing them for future roles in the Embedded of electronics industries. The mentorship and networking opportunities available during the project can lead to valuable connections and potential job offers after graduation.

Keywords: License Plate Recognition, Morphological Operations, Character Segmentation, Template Matching, Sobel Filter, AVR Microcontroller

1.INTRODUCTION

Transportation plays a crucial role in our daily lives, and with the rapid increase in population, the number of vehicles on the road has grown significantly. This rise has led to challenges such as traffic congestion and difficulty in enforcing traffic regulations. Vehicle License Plate Recognition (VLPR) systems offer a practical solution to these problems by automating vehicle identification.

A license plate serves as the unique identifier of a vehicle. Through this identifier, authorities can access essential information such as the vehicle owner's name, insurance details, and the validity of the driving license. This data is particularly useful for traffic enforcement and monitoring.

Various techniques and software tools are available for license plate recognition, with platforms such as OpenCV and MATLAB commonly used for image processing tasks. In this project, MATLAB is employed for processing the captured images and extracting the license plate information. An AVR microcontroller is used to display the recognized license number along with the owner's name on an LCD screen, facilitating real-time monitoring and law enforcement.

2. Literature Survey

Several methods and systems have been developed for License Plate Recognition (LPR), employing various techniques for plate extraction, character segmentation, and recognition. A summary of key research works is presented below:

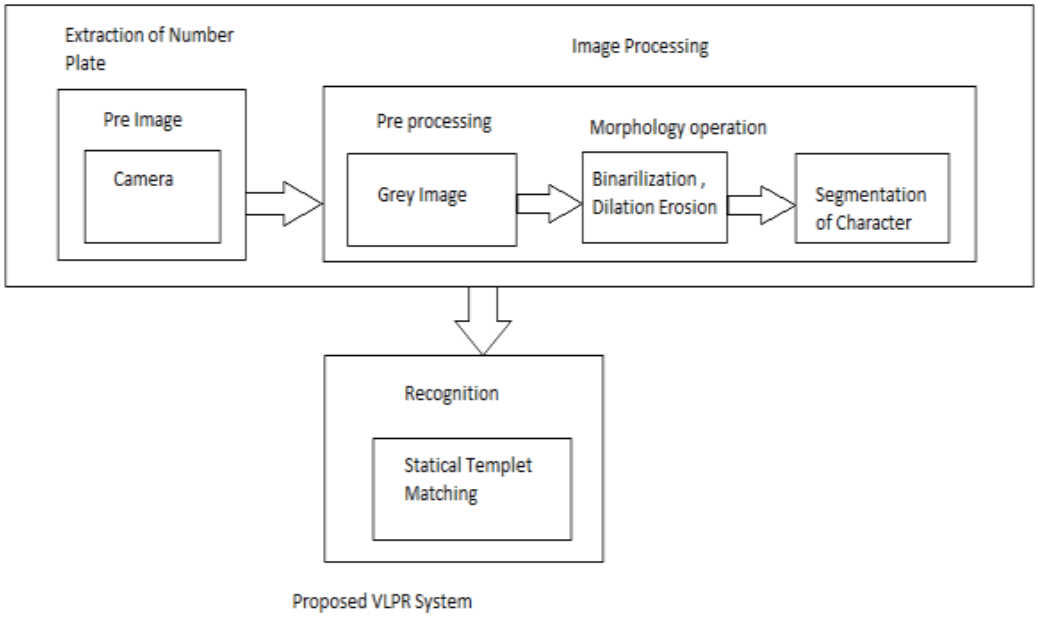
- **License Plate Recognition for Intelligent Transportation System Applications**
  This method uses a Sliding Concentric Window (SCW) approach for license plate extraction, achieving a recognition accuracy of 96%. SCW is also used for character segmentation, yielding 89% accuracy. For character recognition, an Artificial Neural Network (ANN) with a two-layer Probabilistic Neural Network (PNN) is employed.
- **An Efficient Method of Vehicle License Plate Recognition**
  Utilizes the SCW technique for plate detection. Edge detection is used for segmenting characters, while ANN is applied for character recognition.
- **A New License Plate Recognition System Based on PNN**
  This approach uses Bottom-Hat filtering and Otsu's Thresholding for plate extraction. For character segmentation, Column Sum Vector (CSV) charts are employed. Recognition is performed using a Probabilistic Neural Network (PNN).
- **Artificial Neural Networks Based Vehicle License Plate Recognition**
  The system applies a Canny edge detector and Gaussian filter for extracting license plates. For segmentation, it uses a Binary Large Object (BLOB) colouring algorithm. Recognition is carried out using ANN.
- **Multi-feature Based License Plate Detection in Nighttime Environments**
  Implements a variable scanning window for plate detection and horizontal and vertical projection methods for character segmentation.

- **A Novel Approach for Vehicle License Plate Localization and Recognition**
  Uses Canny edge detection and Gaussian filtering for plate localization. Traditional projection methods are applied for character segmentation, and character recognition is done through projection-based methods.
- **Research and Implementation of a License Plate Recognition Algorithm Based on Hierarchical Classification** [7]
  This system uses Wavelet Packet Decomposition and K-L Transform for plate detection, followed by Wavelet Packet Transform for segmentation and LIBSVM (Support Vector Machine) for recognition.
- **Saudi Arabian License Plate Recognition System**
  Applies vertical edge matching for plate extraction, followed by normalization for character segmentation. Template matching is used for final character recognition.
- **Automatic Vehicle Identification by Plate Recognition**
  Utilizes edge detection and smearing algorithms for license plate extraction. Filtering, morphological operations, and smearing are used for character segmentation, with template matching used for character recognition.
- **Automatic New License Plate Recognition in Egypt**
  Achieves 97.60% accuracy in plate extraction using edge detection and smearing algorithms. For character segmentation, smearing, filtering, and morphological algorithms are used, achieving 98.80% accuracy. Template matching is used for recognition.

3.ProposedMethod

The overall framework of the proposed system is illustrated in Figure 1. The method consists of four main stages:

- **License Plate Extraction** – Identifying and isolating the number plate region from the captured image using image processing techniques.
- **Character Segmentation** – Separating individual characters from the extracted license plate.
- **Character Recognition** – Recognizing each segmented character by comparing it with pre-defined templates using cross-correlation.
- **Display via AVR Microcontroller** – Displaying the recognized license number on an LCD using AVR-based hardware for long-distance visibility.



Proposed VLPR System

3.1ExtractionofNumberPlate

This is one of the most critical stages in a Vehicle License Plate Recognition (VLPR) system.

a)Preprocessing:

Since images can be captured using different cameras with varying resolutions, preprocessing begins with resizing the image to a manageable size for efficient processing. In this system, the original image captured has a resolution of **3264 x 2448 pixels** (Figure 1), which is too large for real-time image processing. Therefore, the image is resized to a more suitable resolution of **1315 x 489 pixels** (Figure 2) to optimize processing speed and reduce computational load.

Fig. 1 Original Image

Figure 3. Next, the resized color image is converted into a grayscale image to simplify the processing and reduce computational complexity. To eliminate noise and enhance image quality, a median filter is applied. This filtering step helps in preserving edges while removing unwanted noise from the image, as illustrated in

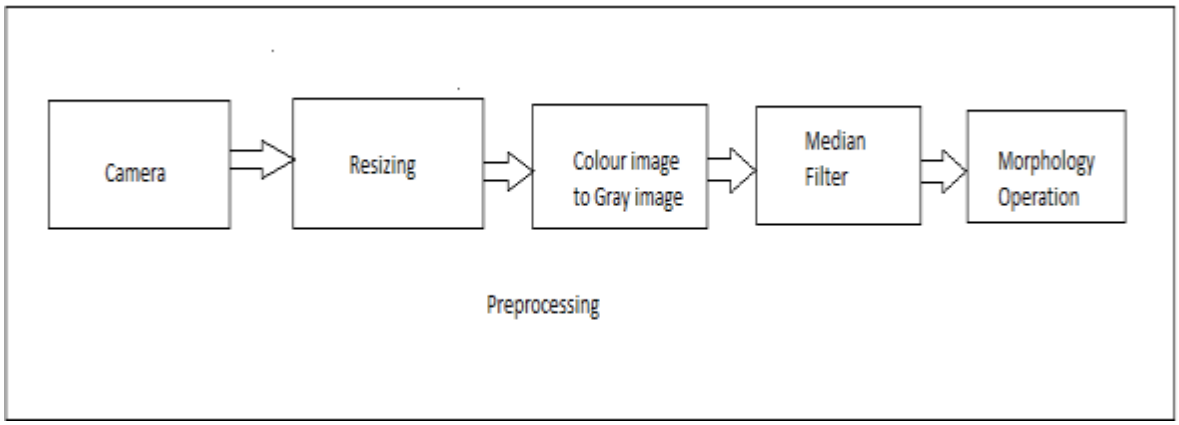


Fig. 2 Preprocessing Steps

Fig. 3 Gray Image

Fig. 4 Complement images

In image processing, the initial step involves converting the RGB image into a grayscale image. This conversion enhances processing speed and simplifies the extraction of the region of interest, such as the license plate. MATLAB provides a variety of edge detection filters including Sobel, Canny, and Prewitt. To determine the most effective method for number plate extraction, these filters were evaluated.

a) SobelFilter:

The Sobel filter, also known as the Sobel operator, is widely used for edge detection. It employs two 3×3 convolution kernels—Gx and Gy—to detect edges in horizontal and vertical directions, respectively. The Gx kernel highlights edges by convolving the image from right to left (horizontal), while Gy focuses on vertical edges by convolving from top to bottom.

$$Gx = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix}$$

$$Gy = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix}$$

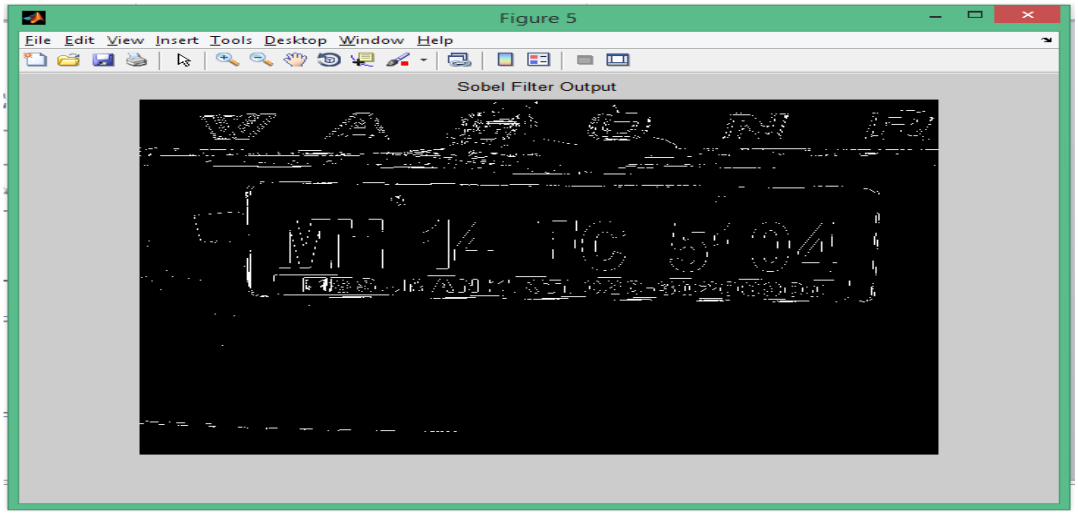


Fig. 5 Sobel filter output

CannyFilter:

The Canny edge detection process begins by applying a Gaussian filter to the image to smooth it and reduce noise. After

smoothing, the intensity gradients of the image are calculated to identify areas with significant changes in brightness, which typically correspond to edges. Non-maximum suppression is then applied to thin out the detected edges and remove any spurious responses. Two threshold values are used to identify potential edges: a high threshold for strong edges and a low threshold for weak ones. Finally, edge tracking by hysteresis is performed, where only the weak edges that are connected to strong edges are preserved, and all other weak edges are suppressed. This ensures accurate and continuous edge detection.

$$\mathbf{B} = \frac{1}{159}\begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} * \mathbf{A}.$$

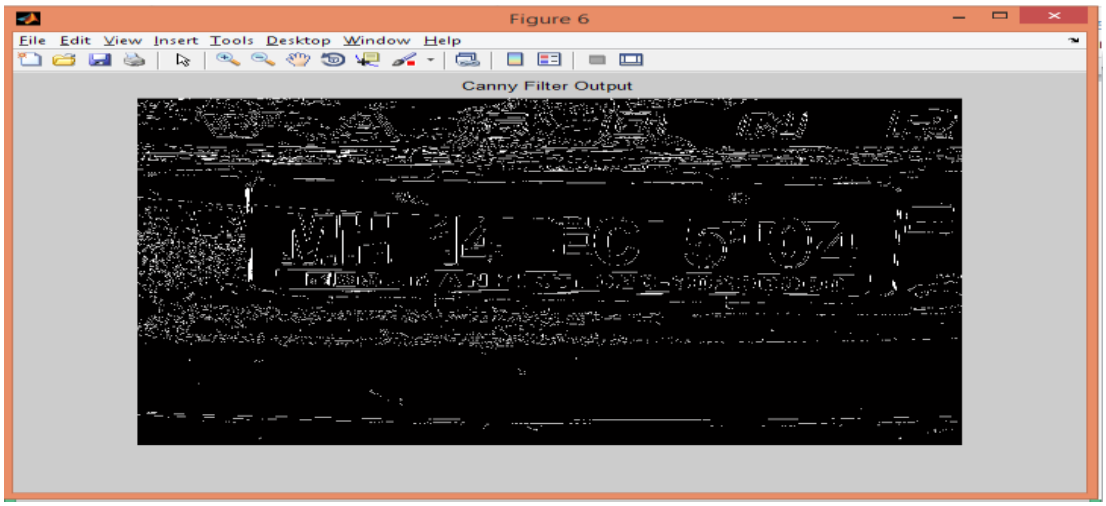


Fig 6. Canny Filter output

MorphologicalOperation:

Morphological operations are performed using two main functions: imdilate and imerode. The imdilate function increases the area of white pixels, effectively expanding object boundaries. In contrast, the imerode function shrinks white regions by converting edge pixels from white to black. By subtracting the eroded image from the dilated one, sharp and continuous edges are obtained, enhancing the overall edge structure.

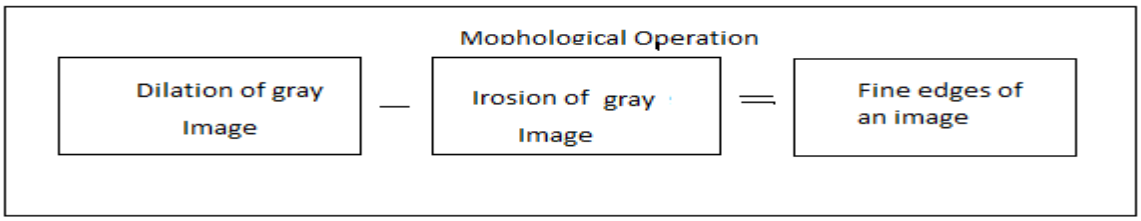


Fig 7 Morphology Operation

In image processing, the first step is to convert the RGB image into a grayscale image. This simplifies the data, improves processing speed, and makes it easier to extract the region of interest. MATLAB provides several edge detection filters such as Sobel, Canny, and Prewitt. To determine the most effective method for number plate extraction, these filters are applied and evaluated.

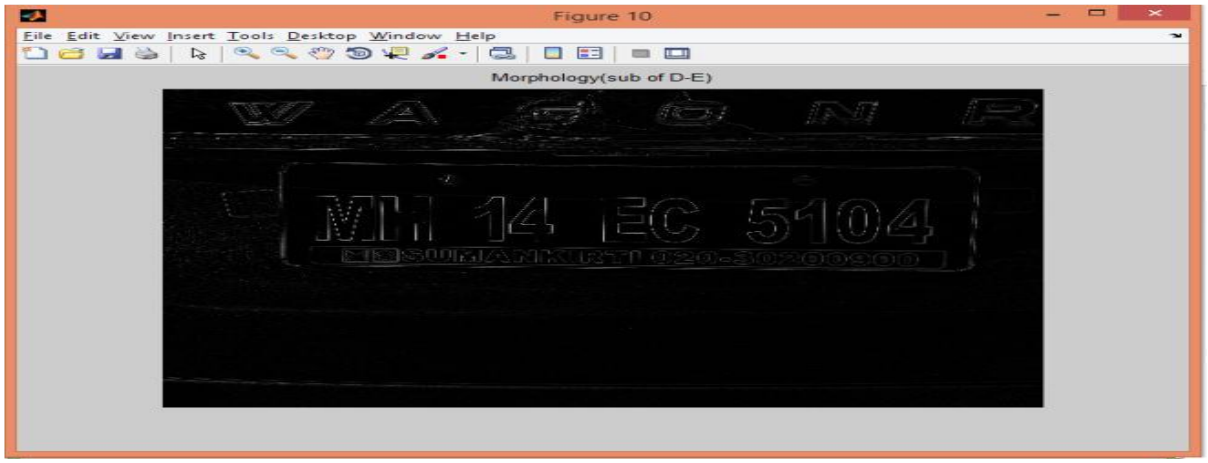


Fig. 8 Morphology Output

3.2 Character Segmentation

Character segmentation is a crucial step in isolating individual characters from the image. At this stage, non-character elements such as screws, extra markings, or laminated areas on the number plate may also be detected as characters. To accurately segment only the relevant characters, a matrix-based method is applied.

After performing morphological operations, the characters are filled with white pixels to enhance visibility. A **vertical projection algorithm** is then used to locate the character regions. This involves comparing potential character areas with a reference size, typically within a tolerance of ±20 pixels.

Next, the algorithm checks for black spaces between two white blobs (potential characters):

- **If a black space exists**, the area is cropped as a separate character.
- **If there is no black space**, the area's white pixel count is analysed:
  - If the count is less than 100 pixels, the region is discarded by converting it to black.
  - If the count is more than 100 pixels, the region is considered a valid character and is cropped for further processing.

3.3 Character Recognition

Once characters and numbers are segmented, each is resized to a fixed block size of 24 × 42 pixels. These blocks are then compared against a stored database of standard characters for recognition, as illustrated in Figure 9 [12].

The recognition process uses statistical correlation, specifically cross-correlation, to match the extracted character with database entries. This method compares two signals — one from the segmented character and the other from the database — to measure similarity. The following equation represents the cross-correlation between two discrete signals.

$$SAD(x,y) = \sum_{i=0}^{Trows} \sum_{j=0}^{Tcols} Diff(x+i, y+j, i, j)$$

Fig.9. Database for template matching

4. GUI

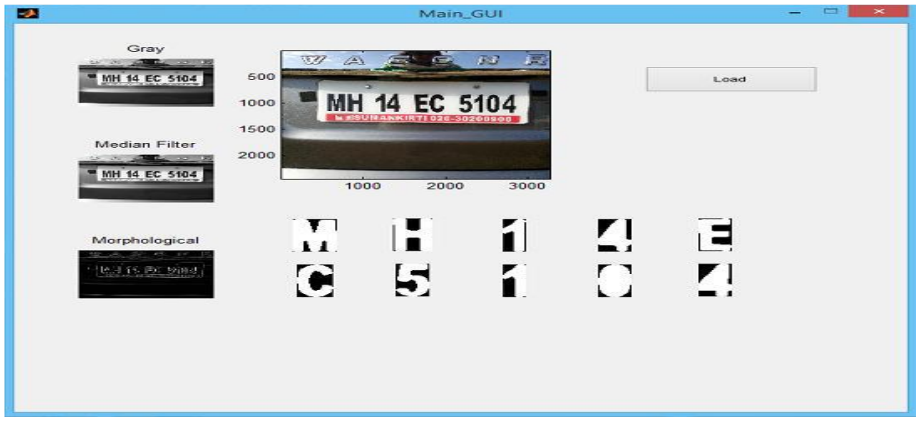


Fig 10 GUI

The graphical user interface (GUI), as shown in Figure 10, displays the entire image processing workflow. It includes the original image captured by the camera, the corresponding grayscale image, the output from the edge detection filter, the result of morphological operations, the segmented characters, and a Load button for image input.

5. Hardware

Hardware is used to display the vehicle's number plate information and the name of the car owner. An AVR microcontroller is employed to establish serial communication between the computer and the display module. Since MATLAB transmits data in 32-bit floating-point format, the data is converted into 8-bit integers before transmission. The serial communication operates at a baud rate of 9600 bps.

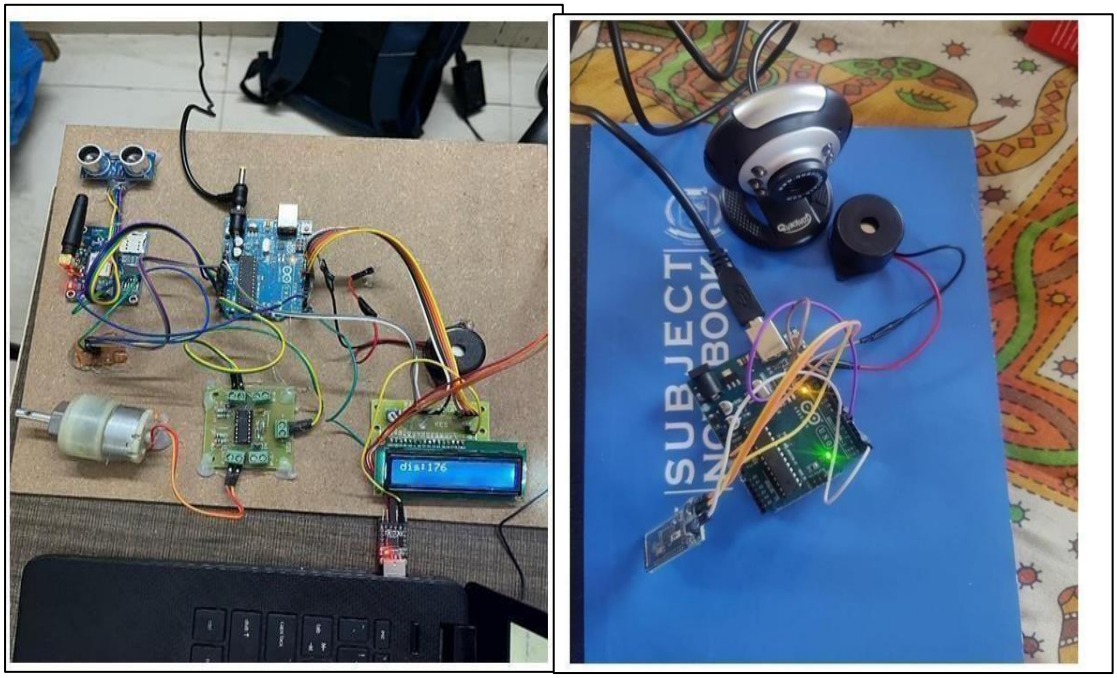


Fig 11 Hardware Implementation

6. RESULT

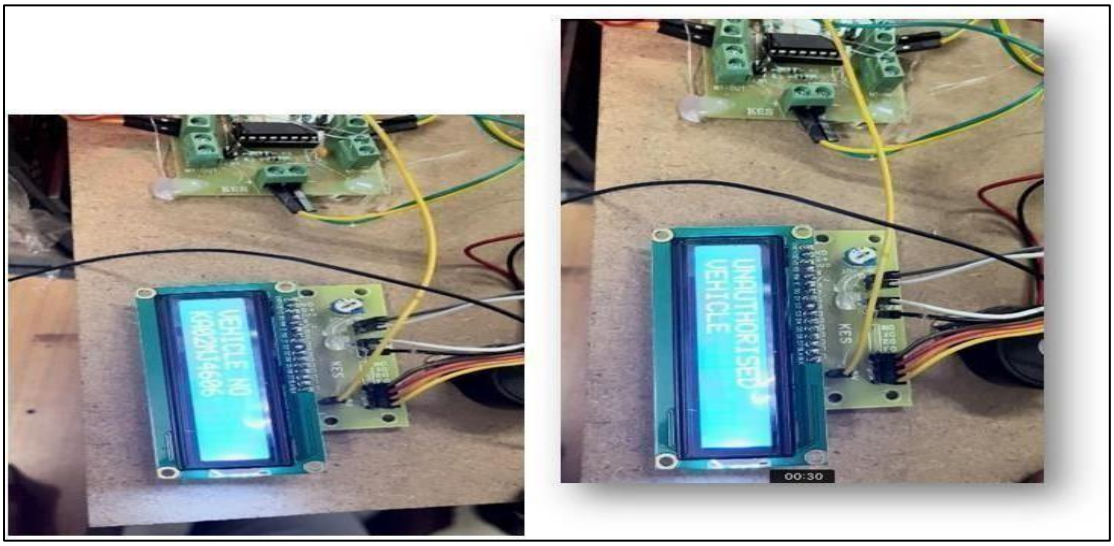
Table 1. Image preprocessing results

Parameters	Sobel Filter	Canny Filter	Prewitt Filter	Morphology Filter
MSE	2.7613	2.7595	2.7603	2.7595
PSNR	13.7196	13.7224	13.7211	13.7224

Based on the table, there is no significant difference in MSE and PSNR values among the filters. However, from the visual analysis in Figures 5 and 8, the number plate appears clearer in the output obtained using the morphological filter. Therefore, it can be concluded that the morphological filter performs better than other filters for this specific application.

Table 2. Results of proposed System

Sr. No.	Parameter	Number Plate extraction	Character Segmentation	Character recognition
1	Number of images	100	100	100
2	Result	90	92	89



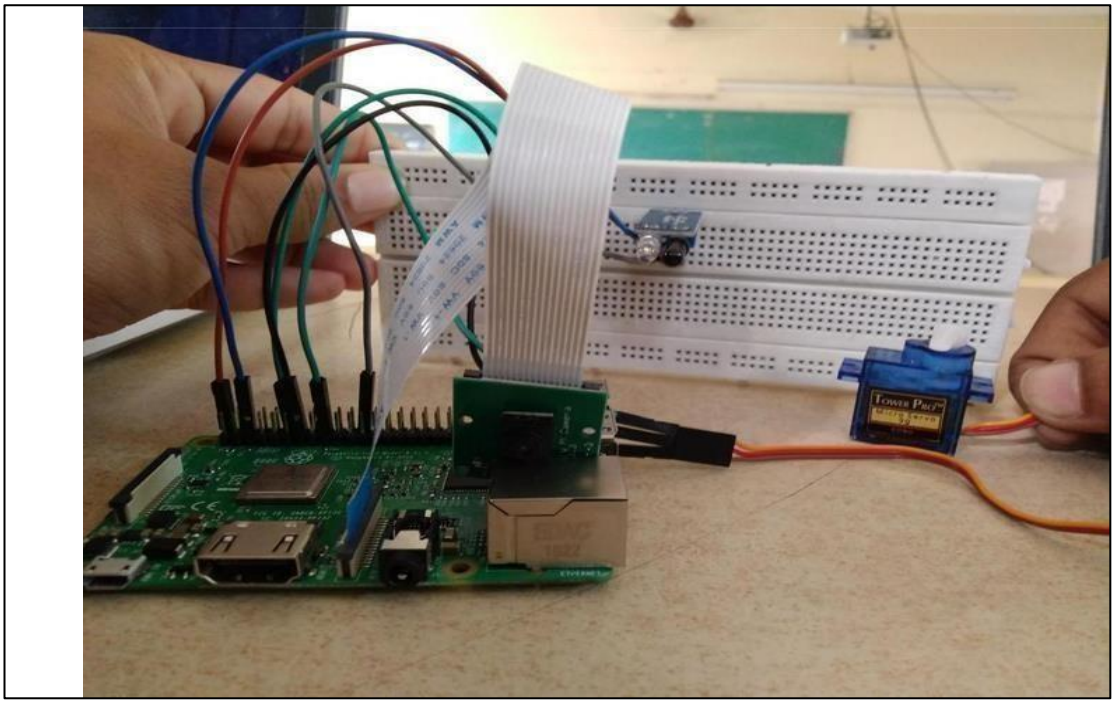


Fig12: Results Implantation

7. CONCLUSION

This system is specifically designed for Indian vehicle number plates. It has been tested on 100 images captured under various environmental conditions. The Vehicle License Plate Recognition (VLPR) system successfully extracted the number plate in 90% of the cases. At the character segmentation stage, the accuracy achieved was 92%, and during the character recognition stage, the system achieved an 89% success rate. The final hardware output was 100% accurate.

One of the major challenges in the Indian context is the lack of standardization in license plates — with varying fonts, shapes, and styles — which affects recognition accuracy. Despite this, the system shows promising results.

FutureScope:
This system can be further developed for real-time applications, particularly for use in security systems across large industries, IT parks, schools, and colleges.

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