Automatic Number Plate Recognition

Final Project Report - Group 5

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***Abstract*—This project aims to develop a comprehensive Automatic License Plate Recognition (ALPR) system that can accurately detect and extract license plate information from vehicle images. The proposed system integrates data collection of vehicle images, frame selection from video streams, preprocessing techniques for image enhancement, and license plate detection using the Marker-Controlled Watershed algorithm for precise image segmentation. Additionally, the system implements a feature-based approach for number plate extraction to ensure accuracy and efficiency. The final output is a web-based application that provides users with a seamless experience for performing ALPR tasks. Experimental results demonstrate the effectiveness and reliability of the proposed system, making it suitable for real-world applications in traffic monitoring and management.**

***Index Terms*—ALPR, Marker-Controlled Watershed Algorithm, OCR**

I. Introduction

The integration of Automatic License Plate Recognition (ALPR) and Traffic Red-Light Running Violation Detection systems represents a significant leap forward in leveraging technology for road safety and traffic law enforcement. These systems offer benefits such as improved traffic management and law enforcement. However, traditional methods for traffic law enforcement, relying on manual observation, are labor-intensive and limited in coverage. There is a clear need for an automated solution that can accurately detect and record traffic violations in real-time.

Our project aims to address this need by proposing an integrated system that combines ALPR technology with a web application. Unlike complex deep learning architectures, our approach leverages traditional image processing techniques, such as the Marker-Controlled Watershed algorithm, for license plate detection.

By emphasizing feature-based methods to detect number plate, our system offers advantages like reduced computational complexity and easier integration into existing systems. We discuss the methodology used, including data collection, image preprocessing, and feature-based license plate extraction, and present experimental results demonstrating the effectiveness of our system.

II. Related Literature Review

Automatic License Plate Recognition (ALPR) systems are pivotal in the Intelligent Transportation System (ITS), facilitating operations like toll payments, traffic monitoring, and vehicle security. Such systems fundamentally comprise license plate location (LPL), character segmentation, and character recognition. The LPL is critical due to diverse image parameters, emphasizing the need for robust methodologies to address challenges posed by varied environmental and operational conditions [1]. Different techniques for LPL include color features, edge extraction, and mathematical morphologies, yet many restrict their applications to controlled settings like indoor scenes or fixed lighting [1]. Innovatively, the integrated features and Marker-Controlled Watershed (IFMCW) algorithm is proposed for better accuracy in complex environments, showing significant improvements over traditional methods [1].

Similarly, automatic number plate recognition is crucial for traffic-related applications. The challenges predominantly lie in variations in number plates and environmental conditions such as lighting and weather, which impede the development of a universal solution. Various algorithms have been proposed, focusing on features like color, shape, or edge information, but often operate under restrictive conditions such as fixed backgrounds or specific distances [2]. Recent studies propose combining multiple features to enhance detection capabilities under diverse conditions, which suggests a shift towards more adaptable and effective recognition systems [2]. This convergence in research highlights the ongoing effort to refine ALPR technologies to be more reliable across variable scenarios, aligning with the advancements discussed in the literature [2].

A. *Preprocessing*

Effective recognition of vehicle license plates involves preprocessing steps to handle interference factors such as illumination, weather, and vehicle speed, which can lead to distortion, blurring, and uneven brightness in plate regions. To address this, images are first converted to grayscale to reduce spatial and temporal complexity. The grayscale conversion is performed using the equation:

$$\text{Gray value} = 0.3R + 0.59G + 0.11B$$

To further refine the process, vehicle number plates, typically rectangular, are segmented using the watershed algorithm. This algorithm identifies distinct regions bound by horizontal and vertical edges. These regions are then smoothed with morphological operations such as dilation and erosion to minimize over-segmentation. The initial and re estimated gradient magnitudes of the image, enhanced by visualization techniques, help in achieving precise segmentation of the number plate, especially when the boundaries obtained by different techniques overlap [2].

The model first processes the vehicle number plate images by ensuring they are noise-free and adjusts the image intensity using a median filter before converting them to grayscale. This is essential for preserving vital information in the image. Next, the gradient magnitude is computed to highlight the borders of objects within the image, where gradients are typically higher compared to the inside of the objects.

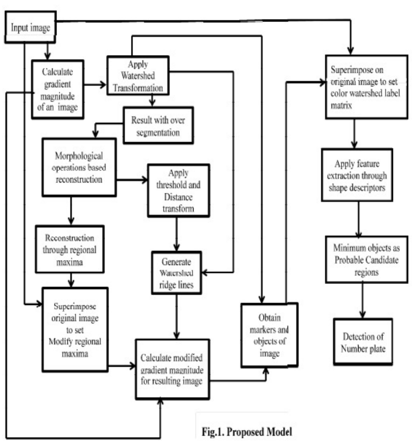

Fig.1. Proposed Model

When applying the watershed algorithm to this gradient data, segmentation often results in over-segmentation. To mitigate these distortions, morphological opening and closing operations are utilized effectively. These operations are designed not to alter the fundamental shapes within the image but rather to clarify the segmentation results. To refine the segmentation further, regional maxima are determined within each region to establish foreground markers, enhancing the segmentation accuracy [2].

Additionally, to handle regions over-segmented by the watershed process, background markers near the object edges in the reconstructed image are removed via thresholding. This step ensures that only significant features are retained. Subsequently, a distance transformation is applied to the resulting image. This transformation helps to separate connected subregions and diminishes less prominent edges and foregrounds, focusing on preserving the centers of regions [2]. This comprehensive preprocessing strategy significantly enhances the clarity and utility of the number plate images for subsequent recognition tasks.

B. Watershed Algorithm

The watershed transform, originally proposed by Digabel and Lantuejoul, is a region-based image segmentation technique extensively utilized in digital imaging. This algorithm is analogous to geographical watershed principles. Imagining a terrain submerged in water, catchment basins fill from local minima, requiring dams at meeting points of different basins to prevent merging. As the water reaches the landscape's peaks, basins are separated by these "watershed lines" effectively segmenting the image.

For an image G, with pixel values $g(x, y)$ he watershed algorithm identifies regional minima and their associated catchment basins. The segmentation process begins by defining the set $T[n]$ as coordinates where $g(s, t)$is less than n :

$$T[n] = \{(s, t)|g(s, t) < n\}$$

The algorithm progresses through incremental flooding stages, where each catchment basin associated with a minimum is expanded:

- **Initial Setup:** Locate the minimum and maximum pixel values in G, assign the coordinates of the minimum to M_i and start flooding in integer increments from $n = min + 1$
- **Catchment Basin Expansion:** For each stage n, expand the catchment basin associated with M_i as:

$$C[n] = \bigcup_{i=1}^{R} C_n(M_i)$$

- **Connected Components Analysis:** In each stage, connected components in $T[n]$ are analyzed to determine if they introduce new minima or extend existing basins. This involves checking if a component intersects with or lies entirely within previous stages.
- **Iterative Expansion:** Repeat the expansion and analysis until n exceeds the maximum pixel value, continuously updating the catchment basins.

To address the common issue of over-segmentation, a marker-controlled approach is employed. Markers are predefined connected components that designate regions of interest (internal markers) and background (external markers). The markers guide the segmentation, ensuring each region is distinctly outlined by controlling the starting points of the flooding process.

After pre-processing the image through noise reduction and intensity adjustments, the next step involves refining segmentation using the watershed algorithm to create watershed ridge lines. The reconstructed image from regional maxima is superimposed on the original to re-estimate regional maxima, enhancing segmentation accuracy. Subsequently, this image, along with the initial gradient magnitude, is used to compute a modified gradient magnitude essential for further watershed transformation. This transformation refines markers and defines objects, and the resulting image is then superimposed on the original to produce a color watershed label matrix, crucial for precise object extraction, such as vehicle number plates in ALPR systems.

The VPM(Vertical Projection Map) of the license plate region shows a discrete pattern, exhibiting periodic and similar peaks and valleys due to successive characters appearing in regular alternation of bright and dark in the horizontal direction.

III. Methodology

A. Data Collection

In the initial phase of our project, we dedicated significant effort to collecting a diverse dataset of vehicle videos. This dataset include frames that ensure high precision and generalizability across various conditions.

- **IIT Hyderabad Main Gate**: We captured several videos of vehicles at different times of the day at our college's main gate. This setting provided us with a range of vehicle types, lighting conditions, and vehicle movements, offering a realistic and challenging dataset for our system.

B. Frame Selection

For the task of optimal frame selection, we have identified a region of interest (ROI) within each frame to focus specifically on the area where the speed breaker is present. This involves specifying the coordinates (x, y) of the ROI relative to the camera's positioning and angle. We then iterate through each frame of the video to find the first optimal frame around the speed breaker where object motion is detected.

This process starts with pre-processing the frame by reducing noise and enhancing contrast. Next, we apply Canny Edge Detection to the ROI and look for a frame with a significant presence of edges in the corresponding edge contour. A certain threshold is defined based on the background to indicate motion detection and the presence of a vehicle in the ROI.

C. Image Segmentation

A grayscale copy of the original optimal frame is created and normalized to the range [0,1]. This normalization ensures that our segmentation technique remains effective across different image types. Subsequently, the gradient of the normalized grayscale image is computed using the Sobel operator.

In the next step, the "Opening-Closing by Reconstruction" operation is applied to the normalized grayscale image. This technique effectively enhances and segments objects in the image while preserving their original shapes and sizes, and further refines the segmented objects by filling in any remaining gaps or holes. We will refer to this image as R.

Foreground markers are extracted from the image R by identifying the regional maxima within small pixel neighborhoods, assigning the local maxima pixels a value of 1, and setting the remaining neighborhood pixels to 0. The modified foreground markers image is further refined through a series of morphological operations such as closing, erosion, and the removal of small objects.

The Euclidean Distance Transform is applied to the Otsu-thresholded binary image of R. Furtherly, the classical watershed technique is employed on this image to obtain the background markers, which include the watershed ridge lines.

Finally, minima are imposed based on the obtained markers and the gradient magnitude image as its minima, while all its intrinsic minima are suppressed. So the regional minima only occur in the marker pixels. These minima serve as initial reference points for the watershed algorithm, which is subsequently applied with the estimated markers and binary mask.

The resulting segmentation is further refined by combining markers with suitable fine-tuned coefficients/weights and dilating the segmentation result to generate the final labels, providing a comprehensive segmentation outcome that distinguishes between foreground objects and the background.

D. License Plate Extraction

Currently, we have our segmented image, labeled in discrete colors. The next task is to extract the license plate. To accomplish this, we will utilize the rectangular properties of the license plate and proceed with the following steps:

- **License Plate Area**: Based on optimal frame selection (ROI) and camera positioning, a threshold minimum area for the license plate is defined. Interested segments meeting this area threshold are retained, while unwanted segments are masked out.
- **Minimum Enclosing Rectangle(MER)**: Each retained segment is individually extracted by masking out the remaining regions based on the unique colors used to label the segments. Corner coordinates of the Minimum Enclosing Rectangle (MER) are calculated for each segment for further processing.
- **Aspect Ratio**: Indian License Number plates follow standard dimensions, which implies a fixed aspect ratio. Undesired regions are further removed by defining a range of acceptable aspect ratios for the MER.
- **Rectangularity**: A binarized copy of each segment is created, and those closely fitting the rectangular property based on MER dimensions are identified. Segments with high ratios of shape area to MER area are considered closer to rectangular shapes, such as rectangles or squares.
- **Verical Projection Map**: The VPM is generated by horizontally traversing each segment and counting the number of white pixels at each instant.

  This VPM vector is normalized, and a custom scoring function is applied to detect the license plate based on unique features such as peak count (number of characters), peak spacing (spacing between characters), peak heights (character projection), and peak width (width of characters).

The parameters involved in this score function are fine-tuned according to our dataset. The VPM with the best score corresponds to the predicted number plate segment.

- **Number Text Extraction**: Finally, the text from the predicted number plate segment is extracted using pytesseract(optical character recognition(OCR) tool).

E. Web Application Development

To make our system accessible and user-friendly, we developed a web application that allows users to upload videos for number plate detection and recognition. This web interface will serve as a platform for users to interact with our system, providing an intuitive and efficient way to process images and view detection results.The corresponding number plate text is extracted and logged.

```
1. Frame selection
   - Initialize a video capture object using a
       video file path.
   - Iterate through each frame in the video.
   - Define criteria for selecting frames of
       interest as discussed above.
   - If a frame meets the specified criteria,
       save it as an image/frame

2. Preprocess images:
   - Convert color images to grayscale.
   - Apply morphological operations to enhance
       and refine the segmentation result.

3. Apply Marker-Controlled Watershed algorithm:
   - Estimate gradient magnitude of the
       grayscale image using the Sobel
       operator.
   - Marker estimation:
        - fgm: Identify regional maxima as
            potential foreground markers.
        - bgm: Threshold the enhanced image to
            obtain a binary mask
        - Compute the distance transform of
            the binary mask and apply
            watershed to obtain background
            markers.

   - Marker Imposition:
      -  impose minima based on the obtained
           markers and the gradient magnitude
           image.
      - Apply watershed with estimated
           markers and binary mask
      - Generate labels by combining markers
           and dilating the segmentation
           result.

4. Determine potential license plate regions
    based on size and aspect ratio
   - Compute minimum enclosing rectangle
   - Check aspect ratio and filter out
       non-plate regions
   - Extract and store bounding box coordinates

5. Characterization of License Plate Regions
   - Preprocess the region (normalize, convert
       to grayscale, threshold)
   - Compute vertical projection profile
   - Score the region based on discussed
       properties and store them

6. Selecting the Best Candidate
   - Choose the candidate with the highest
       score
   - Retrieve the bounding box coordinates of
       the selected region
   - Extract the segmented region from the
       original image using the bounding box

7. Apply OCR using Pytesseract:
   - Use Pytesseract to extract text from the
       preprocessed image.
   - Specify the language and any other
       relevant configurations.
   - Clean up the extracted text (e.g., remove
       noise, filter out non-alphanumeric
       characters).
```

IV. RESULTS

To validate the effectiveness of the proposed method, we test it across various videos, focusing on the performance of the method on the optimal frame.

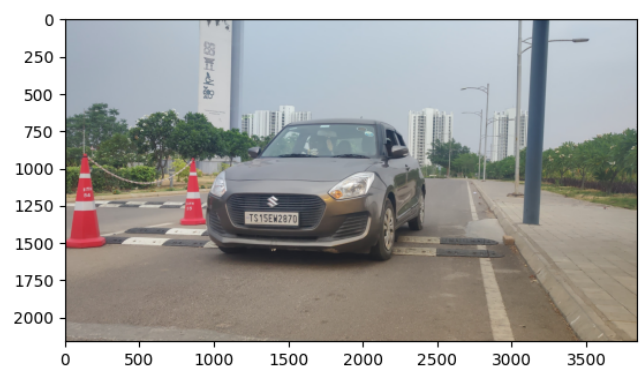

Fig. 1. Selected Frame

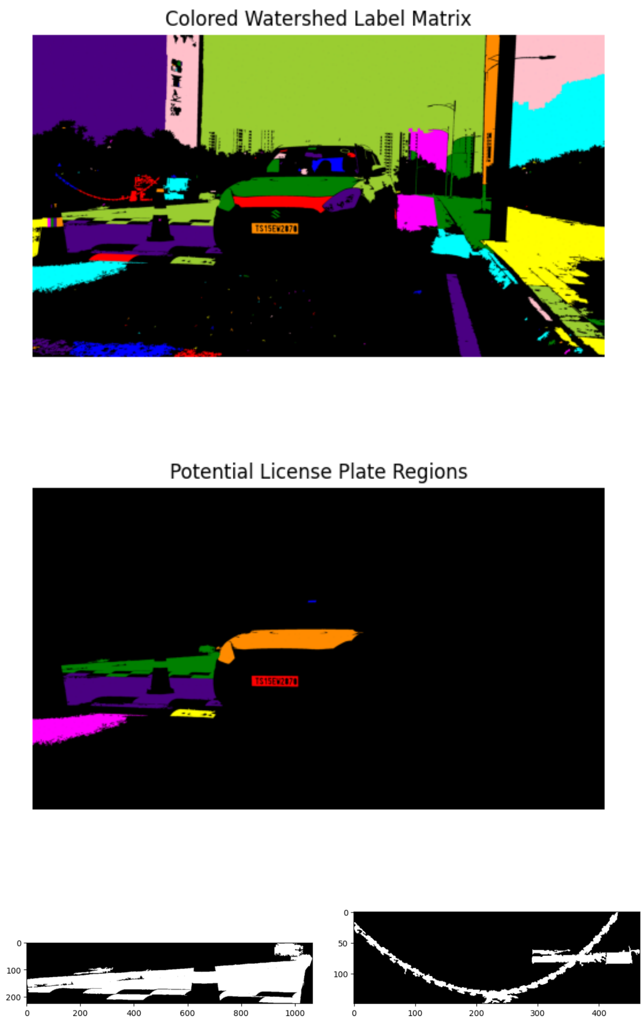

Fig. 2. Segments filtered out by MER Rectangularity property

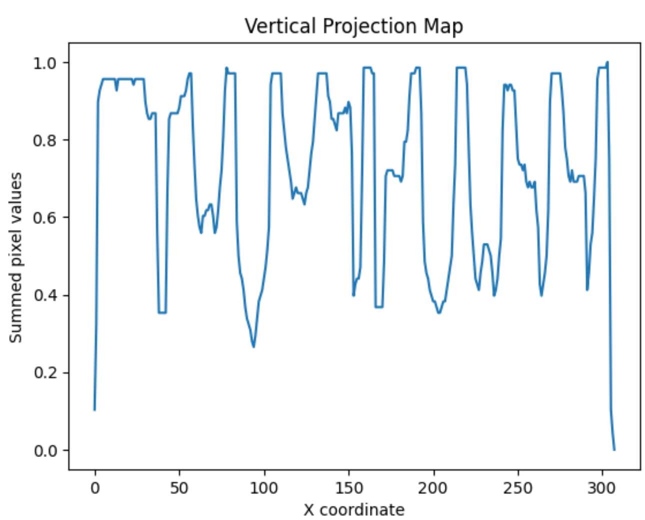

Fig. 3. Desired VPM of our number plate

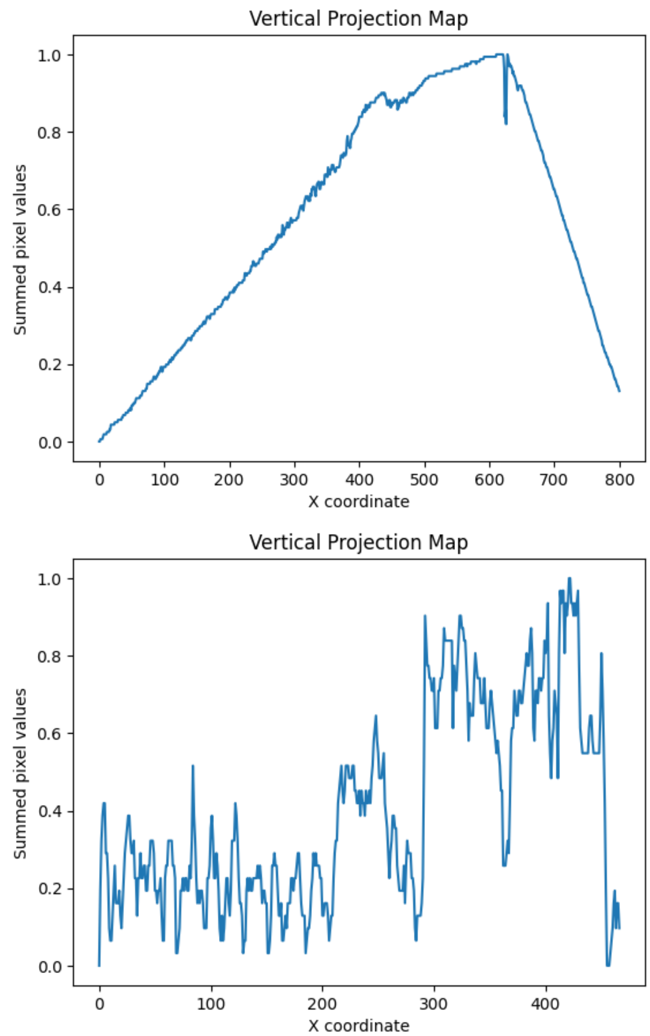

Fig. 4. VPM's corresponding to unwanted segments

Fig. 5. Number Plate Extracted

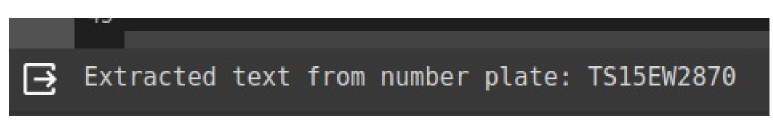

Fig. 6. Text recognized as "TS 15 EW 2870"

Below are two additional instances of successful implementations

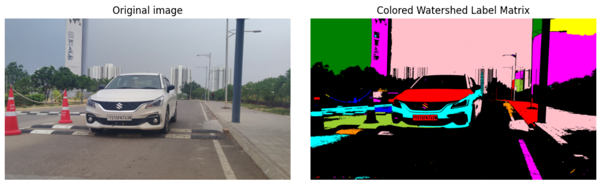

Fig. 7. Original and Segmented Image

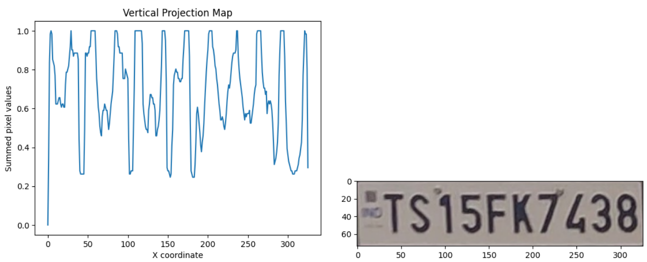

Fig. 8. VPM and extracted plate

Fig. 9. Original and Segmented Image

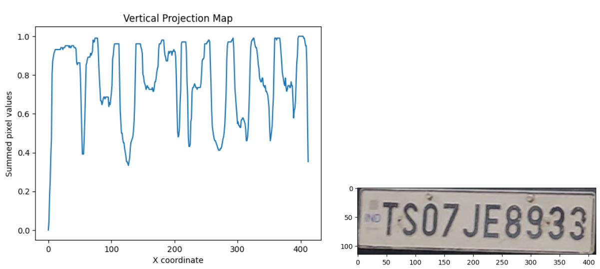

Fig. 10. VPM and extracted plate

Below a situation is shown where our implementation of watershed algorithm has failed.

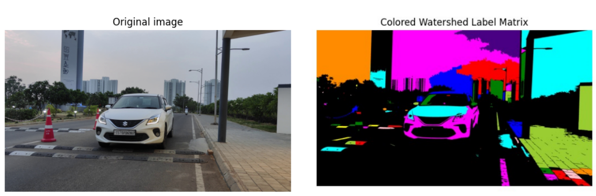

Fig. 11. Number Plate Segmentation Failed

V. Future Work

As we progress toward the final term phase of our project, our focus will shift towards enhancing and expanding the capabilities of our Automatic Number Plate Recognition system. The following key areas will be addressed to fulfill our project objectives comprehensively:

- **OCR (Optical Character Recognition)** The next critical step involves integrating Optical Character Recognition (OCR) technology into our system. This addition will enable the extraction and interpretation of alphanumeric characters from the detected number plates in the images. By leveraging advanced OCR techniques, we aim to achieve high accuracy in number plate recognition, facilitating the identification of vehicles involved in traffic violations.

- **Extending to Real-Time Detection with YOLO** To enhance our system's applicability in real-world scenarios, we will explore the integration of the YOLO (You Only Look Once) model for real-time number plate detection. YOLO's capability for fast and accurate object detection in video streams will allow our system to identify and track vehicles in live traffic conditions, marking a significant advancement in our project's functionality.

- **Traffic Rules Violation Detection** Building on the foundation laid by the number plate recognition and real-time detection capabilities, our final goal is to implement a mechanism for detecting traffic rules violations, specifically focusing on red-light running incidents. By analyzing the real-time video feed, our system will identify vehicles that cross traffic signals when the light is red, automatically flagging them for traffic violations. This feature aims to contribute to road safety and traffic law enforcement efforts.

- **Extending Frame to Various Vehicles** In the upcoming phases, we aim to extend the capabilities of our system to recognize and analyze not only cars but also other types of vehicles, including trucks and motorcycles. By incorporating additional object detection models tailored to different vehicle types, we seek to broaden the scope of our system's applicability in diverse traffic scenarios. This enhancement will contribute to comprehensive traffic monitoring and enforcement efforts, ensuring road safety for all road users.

VI. CONCLUSION

In conclusion, we successfully tried to implement the Marker-Controlled Watershed algorithm based on integrated features.The image in complex background was successfully split into candidate regions and number plate was located in it. The over-segmentaion caused by the traditional Watershed algorithm was successfully resolved by introduction of marker-based controlling.

Dimensionality and other physical contraints were imposed on the candidate regions to filter the desired segments. The unique characteristics of vehicle number plate as demonstrated in VPM was successfully exploited inorder to distinguish it from other segments.

The feature-based approach used in our system proved to be efficient and reliable, offering advantages such as reduced computational complexity and adaptability to different environments.

Furthermore, the project highlighted the importance of leveraging simpler and more interpretable methods in ALPR systems in contrast to complex deep learning models. By emphasizing the use of feature-based methods, our system achieved comparable results while maintaining a higher level of interpretability.

Despite the simplicity of the methods used, the system achieves results in good level of consideration when compared to advanced techniques.

REFERENCES

[1] H. Wang and C. Yuan, "License Plate Location Method Based on Integrated Features and Marker-Controlled Watershed Algorithm," 2010 International Conference on Electrical and Control Engineering, Wuhan, China, 2010, pp. 1234-1237, doi: 10.1109/iCECE.2010.308. keywords: License plate recognition;Vehicles;Image segmentation;Pixel;Transforms;Image color analysis;Image reconstruction;license plate location;integrated features;Marker-Controlled Watershed

[2] M. N. Veena and T. Vasudev, "Localization of vehicle number plate based on watershed transform and visualization technique," 2014 International Conference on Contemporary Computing and Informatics (IC3I), Mysore, India, 2014, pp. 1175-1181, doi: 10.1109/IC3I.2014.7019724. keywords: Image segmentation;Feature extraction;Image color analysis;Vehicles;Visualization;Image edge detection;Transforms;Number plate detection;boundary features;color features

[3] R. Zhang, Yongwu Wu and Y. Zhang, "A method of slant correction of vehicle license plate based on watershed algorithm," 2010 The 2nd International Conference on Industrial Mechatronics and Automation, Wuhan, China, 2010, pp. 95-98, doi: 10.1109/ICINDMA.2010.5538360.