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# Detection and Recognition of Obscured Vehicle License Plates using Image Processing and Machine Learning

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**ABSTRACT:** As cities expand and traffic density increases, automated traffic monitoring has become essential to support law enforcement, tolling, and transportation logistics. Obscured Number Plate Recognition (ONPR) systems are widely used for this purpose, yet they often struggle under non-ideal conditions such as dirt accumulation, mud, glare, or harsh lighting. These factors obscure plate characters and disrupt conventional edge-based or colour-based algorithms. This paper reviews a system designed specifically for recognizing obscured vehicle plates using a combination of optimized hardware components and geometry-driven machine learning techniques. The approach integrates monochrome imaging, infrared illumination, adaptive exposure control, a modified RANSAC-based detection model, quality-aware segmentation, and geometric-feature-based SVM classification. Evaluations on large-scale datasets demonstrate strong detection performance even when plate visibility is severely compromised. The system offers an efficient and interpretable alternative to deep learning ONPR models while maintaining compatibility with resource-constrained embedded platforms.

**KEYWORDS:** Intelligent Transportation Systems (ITS), Obscured Number Plate Recognition (ONPR), Obscured license plates, Image processing, Machine learning, Infrared illumination, Monochrome imaging, Adaptive exposure control, RANSAC, Quality-adaptive segmentation, Support Vector Machine (SVM), Embedded systems, Low-contrast plate recognition.

## I. INTRODUCTION

Intelligent Transportation Systems (ITS) increasingly rely on automated visual processing to manage tasks such as speed enforcement, toll collection, vehicle tracking, and access management. ONPR plays a central role in these applications by converting plate images into digital identifiers. While many commercial ONPR systems perform well in controlled environments, real-world conditions regularly introduce complications. Vehicles traveling on highways or rural routes accumulate dust, mud, and moisture that mask character boundaries and degrade contrast. Illumination changes-especially at night-further reduce clarity.

These non-ideal scenarios present a challenge because standard ONPR pipelines assume distinct edges, uniform backgrounds, and clean reflective surfaces. When these assumptions fail, accuracy drops significantly. Missed detections can lead to loss of enforcement capability, incorrect toll records, or gaps in surveillance. Therefore, specialized methods that can extract plate information despite heavy obscuration are needed. This paper reviews such a system, designed specifically for “dirty plate” conditions and built to operate reliably on embedded hardware.

## II. HARDWARE ARCHITECTURE FOR ROBUST IMAGE CAPTURE

Reliable recognition begins with the quality of the captured image. The reviewed system incorporates hardware choices aimed at maximizing contrast and minimizing noise before the image is processed.

### 2.1 Monochrome Sensors for High Sensitivity

The design employs monochrome cameras for the primary recognition task. Unlike colour cameras, which divide pixels across multiple colour channels, monochrome sensors dedicate every pixel to capturing full luminance information. This design increases light sensitivity and spatial clarity. Under poor lighting or in the presence of mud or dust, this additional sensitivity helps preserve faint character strokes that would otherwise be lost. A secondary colour camera may be included to capture contextual information—such as vehicle colour or environmental details but it is not used for recognition.

### 2.2 Infrared Illumination and Reflective Plate Properties

To maintain visibility at all hours, the system uses infrared (IR) strobes aligned closely with the camera lens. License plates are typically made with retroreflective materials that bounce incident IR light back toward its source. This property causes plates to appear significantly brighter in captured images, making them easier to distinguish even when partially covered by debris.

### 2.3 Synchronized Strobing and Adaptive Exposure

For fast-moving vehicles, the system must eliminate motion blur. This is achieved by synchronizing the IR strobe flash with the camera's exposure window. A narrow pulse of bright IR light freezes motion and ensures a sharp capture. Lighting conditions vary dramatically across environments, so an adaptive exposure mechanism adjusts the exposure time based on feedback from previous frames. If the plate appears washed out, exposure is reduced; if characters appear too dim, exposure is increased. This dynamic regulation ensures consistent image quality.

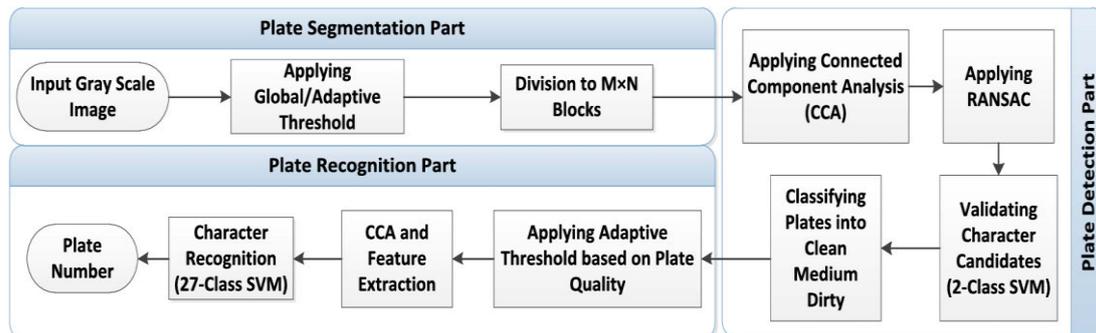


Fig. System Architecture

## III. DETECTION PIPELINE

Once a high-quality image is captured, the system proceeds to locate the plate using algorithms designed to handle partial occlusions and low-contrast conditions.

### 3.1 Motion-Based Region of Interest Extraction

Scanning the full image would be computationally expensive, especially for embedded platforms. Instead, the method identifies moving objects using feature-based optical flow. Distinctive points are tracked across frames, and clusters of consistently moving features are treated as potential vehicles. This produces a region of interest (ROI) that restricts further processing to relevant image sections.

### 3.2 Challenges in Edge-Based Plate Detection

Traditional ONPR systems rely on edge detection or rectangular plate boundaries. However, when plates are covered by dirt, their edges become faint or disappear entirely. Dirt streaks and scratches on the car body may even produce stronger gradients than the plate itself, causing false detections. Because of this, the system avoids edge-dependent detection strategies.

### 3.3 Modified RANSAC for Plate Localization

Instead of detecting a rectangular bounding box, the system searches for the alignment pattern of characters, which generally remain arranged in a straight horizontal line even when partially obscured.

Candidate connected components are identified based on expected character dimensions. These components are sorted by their horizontal position, and pairs with reasonable spacing are evaluated as potential alignment anchors. A modified RANSAC algorithm checks whether additional components fit the same alignment pattern. The method tolerates missing or faint characters, allowing the system to infer the plate's location based on partial evidence.

#### **IV. SEGMENTATION AND RECOGNITION**

Once the plate has been localized, the recognition phase focuses on extracting characters accurately even when their appearance is degraded.

##### **4.1 Plate Quality Classification**

Not all plates require the same processing strategy. A small classifier analyses texture cues and the distribution of candidate components to categorize plates into clean, moderately dirty, or heavily obscured. This classification ensures that segmentation methods are adapted appropriately.

##### **4.2 Adaptive Intensity-Based Thresholding**

Conventional binarization methods like Otsu's thresholding assume a clear separation between foreground (characters) and background. Dirty plates often have overlapping grayscale distributions, making this assumption invalid. To address this, the system compares pixel intensity patterns inside expected character regions with those outside. The threshold is then calculated in a way that enhances faint strokes without amplifying noise. This approach successfully isolates meaningful character shapes even under low contrast.

##### **4.3 Classification Using Geometric Features**

After segmentation, the system extracts geometric descriptors from each character—such as aspect ratios, stroke distributions, and shape curves. These features are fed into a Support Vector Machine (SVM), chosen for its low computational cost and suitability for embedded deployment. Despite its simplicity, the SVM provides stable recognition results when paired with high-quality segmentation.

#### **V. CONCLUSION**

This paper reviewed a system designed to detect and recognize vehicle license plates under challenging real-world conditions, including heavy dirt accumulation and inconsistent lighting. The approach combines specialized imaging hardware with a geometry-centered algorithmic pipeline. Its modified RANSAC detection, adaptive thresholding, and lightweight SVM recognition allow it to outperform traditional ONPR systems on obscured plates while remaining efficient enough for real-time deployment.

As accuracy improves, it is essential to pair such systems with responsible data-management strategies. Ensuring that non-essential data is discarded promptly and that processing occurs as close to the capture point as possible can help balance public safety benefits with privacy concerns. Overall, this integrated hardware–software framework demonstrates that reliable obscured-plate recognition is achievable without relying exclusively on computationally intensive deep learning models.

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