AUTOMATED TOLL PAYMENT AND VEHICLE THEFT MONITORING

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Abstract— **Automated Toll Payment and Vehicle Theft Monitoring is an advanced system that combines computer vision techniques for efficient toll collection and vehicle security. The process begins with detecting incoming vehicles and capturing a front-facing image. The license plate is then located, processed in grayscale to handle various plate colors, and segmented for character recognition using a template matching method. The extracted license number is matched against a database to identify the vehicle category and calculate the applicable toll fee. Upon successful verification, the system lifts the barrier automatically and issues a digital toll receipt. It also records essential information such as the date, time, license number, and toll amount for audit and monitoring purposes.**

Keywords: Automated Toll System, Vehicle Theft Monitoring, License Plate Recognition, Smart Tolling, Number Plate Detection

I. INTRODUCTION

Vehicle Number Recognition (VNR), also referred to as Automatic Number Plate Recognition (ANPR), was first introduced in 1976. However, it garnered increased interest from research groups in the 1990s with advancements in digital photography technology and processing speeds. VNR is a specialized image processing technology that can extract vehicle registration numbers from digital photographs. Using either still or video cameras, the system captures an image of a vehicle, identifies the position of its number plate, and then isolates its characters using a template matching method to change pixel data into numeric or string format. This technology proves useful in a range of applications, including motorway speed enforcement, parking lot automation, and the automation of toll collection systems. The system discussed in this paper is optimized for automating toll tax collection using VNR. Previous techniques had drawbacks, such as relying on color information for detecting number plates, restricting detection to a single color or using computationally expensive color-based search algorithms. Some also relied on the complexity of artificial neural networks. In contrast, the proposed VNR system is color-independent, enabling swift operation in real-time on a regular desktop PC while recog-

nizing multiple standard plates from regions such as Sindh (Yellow), Punjab (Green and White), Government (Green), and Islamabad (White), under proper lighting conditions. for 24 seconds I'm looking at the task to rephrase a paragraph while keeping the meaning intact and the word count the same.

Okay, here's the paragraph about Vehicle Number Recognition (VNR), also known as Automatic Number Plate Recognition (ANPR), which was first introduced in 1976. It gained popularity in the 1990s with the rise of digital cameras and faster processing speeds. VNR is all about extracting license numbers from images, whether captured by stills or videos. It processes the information to automate systems like speeding enforcement, parking, and toll collection. This system is tailored for automatic toll tax collection.

The Vehicle Number Recognition (VNR), or Automatic Number Plate Recognition (ANPR), was introduced in 1976. It became more popular in the 1990s due to the rise of digital cameras and faster processing speeds. At its core, VNR is an image processing technology designed to extract vehicle license numbers from photos. A camera, either still or video, captures an image of the vehicle, after which the system locates the license plate and segments its characters using a technique that converts pixel values into alphanumeric characters.

Vehicle Number Recognition (VNR), also known as Automatic Number Plate Recognition (ANPR), was introduced in 1976. Its development gained momentum in the 1990s with the rise of digital cameras and improved processing speeds. Essentially, VNR is an image processing method that extracts vehicle license numbers from digital images. A still or video camera captures a vehicle's image, then the system accurately identifies the license plate and segments its characters using a template matching method with precision to convert pixel data into alphanumeric information.

II. LITERATURE REVIEW

A typical VNR system is composed of four key modules: image acquisition, license plate extraction, character segmenta-tion, and character recognition. The system's overall efficiency depends largely on the accuracy of the license plate extraction module, for which numerous approaches have been developed. Many common search algorithms rely on color information to

locate the license plate. In these methods, a color search algorithm is used to extract the most likely region of interest from an image. While these algorithms are generally fast, they are limited to detecting only single-colored, standardized number plates.

High extraction rates have been achieved in studies, by employing vertical edge detection combined with mathe- matical morphology operations, capitalizing on the clear verti-cal edges found in English letters and digits. Other approaches incorporate neural networks for license plate extraction. In addition, some methods are specifically designed for recogniz-ing Pakistani vehicle number plates. For instance, the system in uses color searching algorithms to effectively detect Sindh plates, while the approaches in depend on matching the input's vertical edges with the standard plate's width-to-height ratio.

III. METHODOLOGY

A typical VNR system is structured into four main modules: image acquisition, license plate extraction, character segmen- tation, and character recognition. The overall performance of the system hinges largely on the license plate extraction phase, and a variety of techniques have been developed to enhance this step. One common method employs searching algorithms that depend on color information . In these approaches, a color search algorithm is used to isolate the region of interest (ROI) where the license plate is most likely to appear. Although these algorithms are generally quick, they are often limited to detecting single- colored, standardized license plates.

Figure 1. Modules of VNR System

Figure 2. Proposed Algorithm Flow

A. Image Acquisition. Initially, a digital camera captures an image of the vehicle's front. In our system, for simulation, images are taken with a Nokia 5130 at 300x400 resolution; for the prototype model, a webcam is employed. The captured image is then imported into Matlab and converted to grayscale. The final grayscale image is essential for analysis. Figure 3 illustrates the image after conversion to grayscale.

B. Vertical Edging. This step examines the inherent properties of English characters and digits, since these numeral shapes produce sharp edges in the license plate region. This characteristic is exploited for accurately locating the plate within an image. Various methods have been proposed for edge detection, but research demonstrates that the Sobel mask performs significantly better than many alternative techniques .

Figure 3. Grayscale Image   Figure 4. Image with vertical edges

C. Histogram Analysis of Bit Density. In this phase, the bit density of each row in Figure-4 is analyzed via histogram analysis. To do so, the count of ones is computed for every row displayed through vertical projection. Vertical projection is a graph with two axes: the vertical axis represents image rows, and the horizontal axis shows the count of white pixels per row. Figure 5 illustrates the vertical projection of edged image.
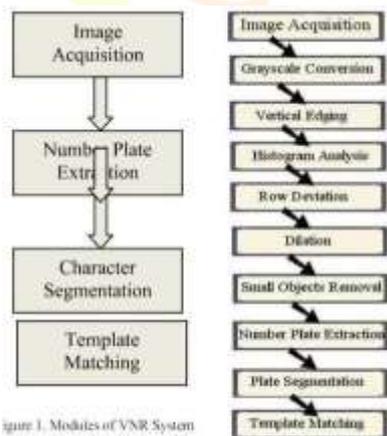

Figure 5 Vertical Projection of bit density

Figure 6. Result of Bit ensity Analysis

D.   Row Deviation. The vehicle's background, including el-ements like trees, can also exhibit vertical edges, leading them to be mistakenly selected as candidate regions in the previous step. Row deviation is applied to counteract this effect. In Pakistan, license plates are typically found in the middle or slightly offset on the vehicle's bumper. Additionally, a license plate possesses vertical edges within a narrow range, whereas background features such as headlights display edges over a wider range. This distinction is exploited in row deviation. By calculating the deviation in each row of vertical edges, candidate regions can be classified with ease. A simple method for this is to count the transitions between "ones" and "zeros" for each row, discarding rows with excessive deviations from the candidate regions [6]. As a number plate's vertical edges are closely spaced, the rows in its region exhibit consecutive points that are entirely "ones" or "zeros" and show minimal deviation. Figure 7 depicts the vertical projection of these rows.
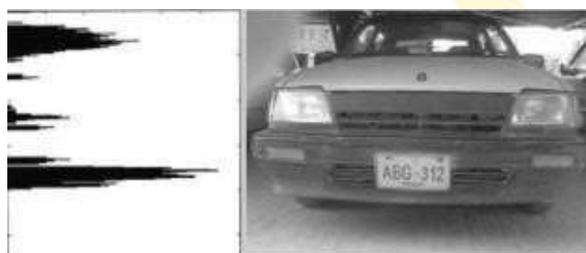

Figure 9. Dilated Image

region. In this step, those small regions are removed. Every region that contains fewer than P pixels is discarded. In this way, only a single object remains in the image that corresponds to the location of the number plate. Next, a 1x15 median filter is applied to the image to create a smooth skeleton of the number plate. The resulting image after removing small objects and median filtering is shown in Figure 9..

Figure 7. Row Deviation Analysis

Figure 10. After Filtering

G.   Number Plate Extraction The image in Figure 10 is multiplied by the original image from Figure 3, and then by applying horizontal and vertical scanning, the number plate is cropped and extracted.

H.   Plate Segmentation In this step, the characters and digits of the plate are segmented, and each is saved as a separate im- age. To do this, the entire number plate is resized to a specific dimension and its region properties are computed. The details of each connected object (i.e., character) in the extracted image are determined. By identifying these properties, the starting and ending coordinates of each character are found, and every character is saved as an image in a matrix cell. Figure 12 displays number plate characters.

Figure 8. Result of Row Deviation

E.   Dilation In this step, a morphological operator is applied. The vertical edge image is first dilated horizontally, then vertically. The structuring elements used are 6-pixel wide lines oriented horizontally or vertically. This dilation connects the characters on the plate, creating a skeletal outline of the license plate. The dilation result is displayed in Figure 9.

F.   Removing Small Objects Median Filtering. Along with the number plate, minor lines may also appear in the candidate

Figure 13. System Hardware Design

Figure 11. Extracted Number Plate   Figure 12. Segmented Number Plate

I.   Template Matching The final stage in vehicle number recognition is template matching. For effective comparison, the extracted characters must be resized to match the stored templates. In this study, characters are represented in 50x30 pixel images. When both the extracted characters from the plate and the stored templates share the same dimensions, each input character is compared against the stored versions using cross- correlation to determine the best similarity. Since Pakistani license plates feature all 36 alphanumeric characters (26 letters and 10 digits), every input character is compared with all 36 templates. During the template matching process, each plate character is correlated with every template, and the character corresponding to the highest correlation coefficient is selected. This uniformity ensures that the matching process is both reliable and efficient. Ultimately, the system reliably identifies each character with optimal precision consistently..

INTERFACING WITH HARDWARE MODEL The VNR

system is integrated with a hardware model and a database to create a fully automated toll tax collection system. The hardware model comprises a proximity sensor that detects an approaching vehicle, a webcam that captures its image, motors that control the opening and closing of the toll plaza barriers, a desktop computer running the VNR algorithm, an LCD and seven-segment display, and a microcontroller that manages all hardware components. When a vehicle arrives at the toll plaza, the inductive proximity sensor senses its presence and sends a signal to the PC via a parallel port. The connected camera captures the front view of the vehicle, and the VNR algorithm processes the image to identify the license number. This recog-nized number is then used to charge the toll tax and generate a receipt containing all pertinent vehicle details. Furthermore, information such as the time, date, license plate number, and toll amount is stored in the database for record-keeping. The PC subsequently sends a signal to the microcontroller using the parallel port, causing the motors to briefly open the road barrier while the LCD displays the message "Please Move Ahead" to guide the vehicle. The complete hardware design of the system is illustrated in Figure 13 for reference..

IV.   RESULTS AND DISCUSSION

Better performance of the system can be achieved when percentage values for a, b P are adjusted based on the camera quality and image resolution. After developing the system, it is set up for testing. The proposed algorithm was designed in Matlab R2007 for recognizing vehicle number
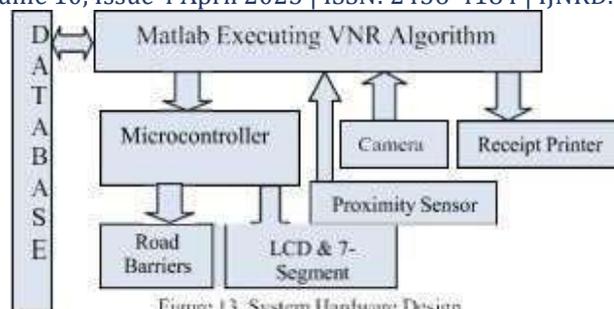
plates. The system utilized a Compaq Evo N610c with a 2.00 GHz processor and 512 MB RAM. The effectiveness of the algorithm was evaluated using images captured under various lighting conditions with a 2-megapixel mobile phone camera (Nokia 5130). For real scenes, the image resolution is set to 400x300 pixels, while for the prototype a webcam is employed to capture real-time images at 640x480 pixels. The system requires an average of 3 to 4 seconds from vehicle detection to barrier opening. This efficient performance and robust hardware integration ensure a smooth, reliable toll collection process under varied conditions.

V.   CONCLUSION

In this paper, we present a real-time and effective approach for vehicle number recognition and its implementation for automated toll collection. The system has been evaluated on numerous images captured under varied lighting conditions, and it can be deployed on motorways and highways for automatic toll tax processing.

Although the proposed system performs well, there remain areas for enhancement. The camera employed in this project is of average quality and is unable to track rapidly changing targets due to its long shutter speed. The system's robustness and speed could be improved by utilizing a high-resolution camera. Additionally, the template matching technique used in this work faces challenges when distinguishing characters such as 8 and B or 0 and O. Incorporating frequency transformation during correlation could further refine the system's number recognition capabilities. This vital enhancement will undoubt-edly contribute significantly to overall system efficiency.

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