TRAFFIC SIGN RECOGNITION USING COMPUTER VISION

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Abstract:

This paper presents a comprehensive study on the development of a traffic sign recognition system based on computer vision, which is crucial for improving road safety and supporting intelligent transport systems (ITS). By using advanced image processing techniques and machine learning algorithms, this research aims to create a reliable system capable of accurately recognizing and classifying various traffic signs. The methodology includes collecting a diverse set of traffic sign images, applying image enhancement techniques, and utilizing deep learning models for precise recognition in different environmental conditions. Experimental results indicate the system's high accuracy in recognizing traffic signs, even in cases with complex backgrounds, demonstrating its potential for integration into autonomous vehicles and advanced driver assistance systems (ADAS). This research contributes to efforts aimed at enhancing road safety and improving traffic management through automated traffic sign recognition.

Keywords:

Traffic Signs, Computer Vision, Machine Learning, Traffic Safety.

INTRODUCTION

Traffic sign recognition (TSR) is an important part of advanced driver assistance systems and autonomous vehicles, helping to improve road safety. [1]. It enables vehicles to recognize and understand signs like speed limits, warnings about children nearby, and upcoming turns [2]. Accurate recognition of traffic signs is especially significant in the context of the development of autonomous vehicles, which must be able to recognize and appropriately respond to various traffic situations in real time. The goal of this paper is to develop a method that can precisely recognize different traffic signs, such as mandatory direction signs and no parking signs. Traffic signs are recognized by their specific colors and shapes, which distinguish them from other objects in the environment, and these properties facilitate their identification in complex conditions.

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Integration with machine learning and deep learning has enhanced the accuracy and efficiency of traffic surveillance, enabling traffic flow monitoring, anomaly detection, and license plate recognition [3]. Deep neural networks have shown exceptional results in recent years in various applications, including object detection and automatic traffic sign recognition [4]. However, challenges such as changing weather conditions, varying angles of observation, changing light conditions, and the variety of sign types make precise identification very challenging, especially in real time.

2. RELATED WORK

This section reviews previous research on traffic sign detection conducted in different parts of the world. Luo et al. introduced a three-stage, information-driven framework for detecting image-oriented and text-oriented signs using a vehicle-mounted camera. Despite its innovative approach, the framework's extensive post-processing stage presented a notable limitation [5]. The study "Traffic Sign Recognition Using CNN" explores the application of convolutional neural networks (CNNs) for accurately recognizing traffic signs. The proposed model leverages deep learning techniques to identify and classify traffic signs efficiently, addressing challenges like variations in size, shape, and environmental conditions. The results demonstrate the potential of CNNs in improving traffic sign recognition systems [6]. U. Venkateshwarulu and Prof. B. Manjunath, in their study "*CNN Model for Traffic Sign Recognition*," propose a convolutional neural network (CNN)-based approach for traffic sign detection and classification. Their model addresses challenges such as varying lighting conditions and occlusions, demonstrating improved accuracy and reliability in traffic sign recognition systems [7]. The study "Small Traffic Sign Recognition Method Based on Improved YOLOv7" introduces an enhanced YOLOv7 model specifically designed for recognizing small traffic signs. By optimizing the network structure and incorporating advanced detection techniques, the authors address challenges related to the detection of small and distant signs, achieving improved recognition accuracy and performance [8]. Rahul Patil [9], in his paper "Real-Time Traffic Sign Detection and Recognition System Using Computer Vision and Machine Learning," introduces a system that integrates computer vision and machine learning for real time traffic sign detection and recognition. The approach focuses on achieving high speed and accuracy, making it suitable for applications in advanced driver assistance systems and autonomous vehicles.

3. METHODS AND MATERIALS

The problem of traffic sign recognition encompasses two key components: detection and classification. Detection refers to locating the traffic sign within an image or video, while classification involves determining the type or category of the sign. Both processes are essential for the successful application of computer vision in recognizing traffic signage [10]. Signs are typically recognized through digital images captured by cameras on vehicles, traffic cameras, or other devices. Recognition can be quite complex because signs vary in position, size, and angle, and are often partially obscured by other objects or illuminated under different weather conditions [11]. To address this challenge, various techniques are used, including shape and color-based classification, feature detection, deep learning, and image segmentation methods. The goal is to achieve high accuracy in recognizing traffic signs, thereby enhancing road safety and reducing traffic accidents. These techniques are often combined to improve precision, with the choice of appropriate technology depending on the specific conditions of traffic sign recognition, available data, and computational resources.

3.1. DATASET

In preparing for this study, data collection involved a diverse set of images captured from real-life traffic situations, ensuring a comprehensive representation of various traffic scenarios. A total of 200 images were included in the dataset. The images were selected to cover a range of conditions, such as different angles, lighting situations, and sign types, allowing for a robust evaluation of the system's performance. This dataset was used to assess the effectiveness of the traffic sign detection system and its applicability in real-world environments.

3.2. IMAGE PROCESSING

Digital image processing has evolved significantly since its inception in the 1960s at Bell Laboratories [12]. It is a crucial component in the development of systems like traffic sign recognition, where the goal is to extract meaningful information from digital images or video frames. Image preprocessing techniques significantly contribute to enhancing the accuracy and efficiency of deep learning models for image classification tasks [13]. It involves various techniques and algorithms designed to enhance image quality, detect features, and classify objects accurately. This step focuses on preparing raw images for further analysis.

3.2.1. Loading an image

When loading an image, the first step is to import the required library. Then, the cv2.imread() function is used to load the image, storing the result in the variable img. This function accepts two parameters: the image file path and an integer specifying whether the image should be loaded in color or grayscale (stored in img_1). To display the image in a new window, the cv2.imshow() function is called, which requires the window name and the image variable as parameters [14]. The waitKey() function is then executed to pause the program until a key is pressed. Once a key is detected, the destroyAllWindows() function is invoked to close all open windows.

3.2.2. Converting an RGB image to grayscale

Grayscale in image processing refers to representing an image using varying shades of gray, ranging from black to white, with adjustable intensities. To create a grayscale image, you can either load the file directly in grayscale mode or, if an RGB image is already loaded, convert it to grayscale using the cvtColor method from the OpenCV library [15]. In a grayscale image, each pixel is assigned a value indicating its brightness, where 0 represents black and 255 represents white in an 8-bit image. Converting an image to grayscale can also be done using the PIL (Python Imaging Library) or Pillow libraries [16].

3.2.3. Edge detection

Edge detection is a fundamental technique in image processing and computer vision, with various methods available for extracting object contours and boundaries [17]. The contours of an object can be used to define edges, which serve as fundamental elements of an image. Various algorithms are available for detecting edges, and this paper provides a comprehensive analysis of several edge detection methods, including Prewitt, Sobel, Canny, Roberts, Laplacian of Gaussian, and others.

Figure 1. Sample images from the dataset

Figure 2. Original loaded image

Figure 3. Grayscale Image Format

Figure 4. Edge Detection in Image Processing

Figure 5. Edge Detection in Image Processing

3.2.4. Noise removal

Image restoration focuses on enhancing the quality of an image by eliminating or minimizing various types of degradation, such as blur, noise, or compression artifacts. Python provides multiple libraries for image processing, including OpenCV, scikit-image, and Pillow, which can be leveraged for image restoration tasks. One of the most common restoration techniques is image denoising, which aims to reduce noise in an image, thereby improving its clarity and overall visual quality.

In conclusion, Python provides a robust set of libraries and tools for image processing, establishing it as a versatile and powerful language for a wide range of image-related tasks. By combining these techniques, image processing enables efficient and accurate recognition of traffic signs, which plays a pivotal role in improving road safety and supporting automated traffic management systems.

4. RESULTS AND DISCUSSION

First, the image is loaded. The system then applies image enhancement techniques and uses a pre-trained deep learning model to recognize traffic signs. After detecting the signs, bounding boxes are drawn around them to highlight the findings. The processed image with traffic signs is displayed to the user. The following is the pseudocode of the application:

Table 1 presents the results of traffic sign detection. The table lists different traffic sign types, along with the total number of signs and the number of signs that were successfully recognized by the system.

Based on the results, the system successfully recognized 168 out of 200 traffic signs, achieving an accuracy of 84%. These results indicate a high level of system efficiency in real-world conditions, despite variations in lighting, angles, and surroundings.

```
Load the image
   If the image is not successfully loaded:
       Display the message "Unable to load the image"
       Exit the program
Preprocess the image using image enhancement techniques
Load the pre-trained deep learning model for traffic sign detection
Detect traffic signs in the image using the model
For each detected traffic sign:
   a. Draw a rectangle around the traffic sign
Display the image with the detected traffic signs
Wait for the user to press any key
Close the image window
```

Listing 1. Pseudo code of the application

Table 1. Traffic Sign Detection Results

Traffic Sign Type	Total Signs	Recognized Signs
Speed Limit 30 km/h	25	22
Speed Limit 50 km/h	20	15
Mandatory Right Turn	18	15
Mandatory Left Turn	18	14
Mandatory Go Straight	15	13
No Left Turn	15	12
No U-Turn	14	12
Stop Sign	24	21
Marked Pedestrian Crossing	15	13
One-way Traffic Prohibition	19	16
Two-way Traffic Prohibition	17	15
Total	200	168

5. CONCLUSION

The traffic sign recognition system developed in this study represents a significant step toward safer and more efficient traffic management, providing drivers with timely alerts on key traffic signals, thereby reducing the risk of errors and enhancing overall safety. Such systems can be applied to older car models that lack advanced built-in technologies, offering a practical and affordable option for improving road safety. This is particularly relevant in Bosnia and Herzegovina, where the average age of vehicles exceeds 20 years. To make the system even more reliable and ready for broader application, further improvements are necessary, especially in adapting to different weather conditions, lighting, and complex traffic scenarios. Future research should focus on optimizing recognition models and refining algorithms to fit specific traffic contexts. In this way, traffic sign recognition technology can reach its full potential, becoming a key component of advanced driver assistance systems and modern transportation systems, providing significant benefits to all traffic participants while enhancing road safety.

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