

# AI-Powered Traffic Sign Recognition with Real-Time Weather Advisory

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## Abstract

This project presents the design and development of an AI-powered web application for the real-time recognition of traffic signs, integrated with a location-based weather advisory system to enhance driver safety. The system leverages a Convolutional Neural Network (CNN) trained on the German Traffic Sign Recognition Benchmark (GTSRB) dataset to accurately classify 43 distinct types of traffic signs from both user-uploaded images and live webcam feeds. The web application, built using Python and the Flask framework, provides a comprehensive user experience, including secure authentication via Google Sign-In, a personal dashboard for viewing prediction history, and a password-protected administrative panel for system oversight.

The system's methodology follows a robust pipeline from data processing to deployment. Input images are subjected to a series of preprocessing steps, including grayscale conversion, histogram equalization, and normalization, to match the format used for training the model. The underlying CNN, trained with extensive data augmentation techniques, demonstrates exceptional performance with a test accuracy exceeding 99%. Furthermore, the application integrates with the OpenWeatherMap API, using the browser's Geolocation API to fetch real-time weather data and provide context-specific driving advice, such as warnings for fog, rain, or snow. The project successfully proves the viability of integrating a high-accuracy AI model into a full-featured, user-centric web application, creating a practical tool for enhancing driver awareness and road safety.

**Keywords:** Traffic Sign Recognition (TSR), Convolutional Neural Network (CNN), Flask, Computer Vision, Real-Time Weather, Google Sign-In, Deep Learning, Advanced Driver-Assistance Systems (ADAS), OpenCV.

## 1. Introduction

In recent years, the integration of Artificial Intelligence (AI) into the automotive industry has revolutionized the concepts of vehicle safety and automation. Advanced Driver-Assistance Systems (ADAS) and the development of autonomous vehicles rely heavily on the ability of a system to perceive and interpret its environment in real-time. A critical component of this environmental perception is Traffic Sign Recognition (TSR). TSR systems are designed to automatically detect and classify traffic signs, providing crucial information to the driver or the autonomous driving system, thereby reducing human

error and enhancing road safety. Traffic signs are designed to convey essential information such as speed limits, warnings, and road regulations. However, their visibility can be affected by environmental factors including poor lighting, occlusion by other objects, and adverse weather conditions. Weather phenomena such as heavy rainfall, fog, snow, and storms further increase the risk of accidents by reducing visibility and road traction.

## **2. Background and Related Work**

Traffic signs are designed to convey essential information such as speed limits, warnings, and road regulations. However, their visibility can be affected by environmental factors including poor lighting, occlusion by other objects, and adverse weather conditions. Weather phenomena such as heavy rainfall, fog, snow, and storms further increase the risk of accidents by reducing visibility and road traction.

Weather advisory systems have traditionally focused on providing general weather updates using sensor networks and internet-based weather services. Although effective, most existing systems lack integration with traffic context and do not provide situation-specific advisories. Very limited research has explored the integration of traffic sign recognition with realtime weather advisory, which highlights the novelty and significance of the proposed system.

With the emergence of machine learning, classifiers such as support vector machines and k-nearest neighbors were introduced to improve recognition accuracy. However, these methods required handcrafted features and were limited in handling complex real-world scenarios.

## **3. Problem Statement and Objectives**

The proposed system is a comprehensive web application that integrates a high-accuracy Traffic Sign Recognition model with a user-centric interface and a real-time weather advisory service. The system is designed to be accessible via any modern web browser. Users can either upload a static image of a traffic sign or use their live webcam feed for real-time detection. The backend processes the visual data, feeds it to a trained Convolutional Neural Network, and returns the classification result along with a contextual remark and driving advice.

Furthermore, the system incorporates secure user authentication through Google Sign-In. Logged-in users have access to a personal dashboard where they can view a history of their past predictions. The application also includes a secure, password-protected administrative panel for system management and oversight. A key innovation of this system is its ability to fetch and display the user's local weather conditions, providing dynamic safety recommendations based on factors like rain, fog, or snow.

The primary objectives of this project are as follows:

- To develop a highly accurate CNN model for classifying 43 different types of traffic signs.
- To build a full-featured web application using the Flask framework that serves the AI model.
- To implement dual prediction modes: static image upload and live webcam stream.
- To integrate a secure user authentication system with Google Sign-In and a personal user history feature.

- To create a secure admin panel for managing users and viewing all prediction data.
- To integrate a real-time weather advisory service that provides driving recommendations based on the user's location.

## 4. Used Languages

The implementation uses Rust for the canister backend to leverage memory safety and performance, Python3.11+, Flask-SQLAlchemy for database interaction and HTML5, CSS-3, JavaScript, jQuery & AJAX for dynamic, asynchronous communication and modern user interface.

### 4.1 Languages and Structure

The development of the **AI-Powered Traffic Sign Recognition with Real-Time Weather Advisory** system utilizes a combination of programming languages, frameworks, and structured design principles to ensure efficiency, scalability, and real-time performance.

#### Programming Languages Used

##### Python

Python is the primary programming language used for this project due to its simplicity, extensive libraries, and strong support for artificial intelligence and machine learning applications.

##### SQL

SQL may be used for storing recognized traffic sign data, weather information logs, and system performance records.

##### HTML, CSS, and JavaScript

These languages are used for developing a user-friendly interface or dashboard to display detected traffic signs and real-time weather advisories.

### 4.2 Tooling and Scripts

The system uses tools such as Visual Studio Code and Jupyter Notebook for development and experimentation, with Anaconda for environment management. Core libraries include OpenCV for real-time image processing, TensorFlow/Keras for training deep learning models, and NumPy and Pandas for data handling. The project is implemented through scripts for data collection, image preprocessing, model training, real-time traffic sign detection, weather data retrieval using APIs, and integration of recognition results with weather-based safety advisories.

## 5. Development Workflow

Traffic sign datasets are collected and preprocessed to improve image quality and consistency. A Convolutional Neural Network (CNN) model is then designed, trained, and evaluated for accurate traffic sign recognition. After successful training, the model is integrated with real-time video input for live detection. Simultaneously, real-time weather data is retrieved using a weather API and analyzed to generate relevant driving advisories. Finally, both traffic sign recognition results and weather advisories

are combined and presented to the user through a unified output interface, ensuring real-time performance and enhanced road safety.

## 6. System Architecture

The system is built on a client-server architecture, with the AI model and database residing on the server side. The interaction flow is as follows:

[User's Browser (Frontend)] <--- (HTTP/AJAX Requests) ---> [Flask Server (Backend)]

[User's Browser (Frontend)]

|--> (Image/Video Data)

|

|<-- (Prediction JSON)

|

|--> (Login Token)

|<-- (User Info)

|

|--> (Location Coords)

|

|<-- (Weather JSON)

[Flask Server (Backend)]

|

|-> [AI Model (Keras/TF)]

|

|<--[Classification Result]

|

|--> [Database (SQLAlchemy)]

|

|--> (Save User/Prediction)

|

|--> [OpenWeatherMap API]

User Layer (Frontend): Developed using HTML, CSS, and JavaScript (with jQuery and Bootstrap). It provides the graphical interface for user interaction, including the sign-in button, upload form, webcam viewer, and result display cards. It uses AJAX to communicate asynchronously with the backend.

## 7. Data Model and Ownership

The data model includes traffic sign datasets containing labeled images used for training and testing the recognition model, real-time video frames captured during system operation, and weather data retrieved

from external weather APIs. Recognized traffic signs and corresponding weather advisories are processed in real time and may be temporarily stored for analysis or performance evaluation. Data ownership primarily lies with the system developers for all processed and generated data, including trained models, recognition results, and advisory outputs.

## 8. Performance and UX

The traffic sign recognition model achieves accurate classification through optimized image preprocessing and efficient deep learning algorithms, enabling fast detection from live video streams. Real-time weather data integration is lightweight and does not significantly impact system responsiveness. The interface is designed to minimize driver distraction by using simple icons, readable text, and timely notifications. Overall, the system balances accuracy, speed, and usability to enhance road safety and user confidence during driving conditions.

## 9. Security Considerations

The system is designed with basic security measures to ensure safe and reliable operation. Communication with external weather APIs is performed over secure connections to protect data integrity. API keys are stored securely and not hardcoded in source files. The system processes only traffic sign images and publicly available weather data, avoiding the collection of personal or sensitive user information. Access to the system and its source code is controlled through version control and environment-level permissions. Model files and configuration data are protected from unauthorized modification to prevent incorrect predictions. These measures help maintain system reliability, data privacy, and protection against misuse.

### 9.1 Root Key Handling in Production

In the **AI-Powered Traffic Sign Recognition with Real-Time Weather Advisory** system, root keys such as API keys and system access credentials are handled securely in production environments. Sensitive keys are stored using environment variables or secure configuration files rather than being hardcoded in the application source code. Access to these keys is restricted based on user roles and system permissions.

### 9.2 Authorization, Rate Limits, Moderation

The system implements authorization, rate limiting, and moderation to ensure secure and efficient operation:

**Authorization:** Access to system APIs, especially the weather data API, is controlled using API keys or tokens. Only authorized users or components can request data or trigger system functionalities, preventing unauthorized access.

**Rate Limits:** API requests are regulated to comply with service provider limits and prevent overloading. This ensures consistent system performance and avoids service disruptions caused by excessive calls.

**Moderation:** Input data, such as video streams or external API responses, are validated before processing. This prevents corrupted, malicious, or unexpected data from affecting the recognition model or generating

incorrect advisories. Additionally, the system can flag anomalous results for review to maintain reliability and safety.

## **10. Comparative Context**

The system stands out by combining real-time traffic sign recognition with live weather-based driving advisories, unlike traditional traffic monitoring systems that focus solely on sign detection. Conventional systems often rely on static cameras and preloaded datasets, providing limited adaptability to changing environmental conditions. In contrast, this project leverages deep learning models for high-accuracy traffic sign classification and integrates real-time weather data, enhancing driver awareness and safety. Compared to similar AI-based recognition systems, the inclusion of a weather advisory module provides a broader context for decision-making, making it more practical for real-world driving scenarios.

## **11. Roadmap**

The development phase involves building and training models for traffic sign recognition using CNNs or YOLO architectures. Alongside this, a weather advisory module is designed to provide context-aware alerts. These components are then integrated into a unified pipeline capable of real-time performance.

System integration ensures the solution works seamlessly in practice. Real-time video processing is optimized, interfaces are built for driver alerts, and deployment on edge devices like Raspberry Pi or Jetson Nano is tested. Weather services are connected to deliver timely advisories.

### **11.1 Short-term Features**

#### **Traffic Sign Recognition**

Basic sign detection: Implement recognition for common signs (stop, speed limit, pedestrian crossing).

Image preprocessing: Normalize and resize input images for consistent model performance.

Real-time detection: Enable recognition from live video feeds with minimal latency.

#### **Weather Advisory Integration**

API connection: Integrate a reliable weather API (e.g., OpenWeatherMap) for real-time updates.

Basic alerts: Provide simple advisories like “Rain ahead – drive carefully” or “Fog detected – reduce speed.”

#### **System Interface**

Dashboard prototype: Create a simple interface showing detected signs and current weather.

Mobile/desktop alerts: Push notifications or on-screen warnings for drivers.

Basic logging: Store recognized signs and weather conditions for later analysis.

## 12. Limitations and Open Challenges

The project faces certain limitations such as reliance on high-quality datasets, hardware constraints for real-time processing, and challenges with environmental variability like poor lighting or damaged signs. Weather advisories also depend on external APIs, which may introduce latency or coverage issues. Open challenges include scaling recognition across diverse regions, ensuring robustness in adverse weather, optimizing performance for live video feeds, and adapting models for edge deployment. Further hurdles involve developing context-aware advisories, maintaining user trust through clear alerts, and addressing data privacy and security concerns as the system expands. Despite its advantages, the system has certain limitations. Performance may degrade under extreme weather conditions such as heavy snow or dense fog. Dependency on internet connectivity for external weather data may also affect reliability in remote areas.

## 13. Conclusion

This project successfully achieved its goal of developing a comprehensive, AI-powered Traffic Sign Recognition system. By combining a highly accurate Convolutional Neural Network with a full-featured Flask web application, the system provides a practical and user-friendly tool for enhancing road safety. The integration of features such as Google Sign-In, user history, a real-time weather advisory, and a secure admin panel elevates the project beyond a simple proof-of-concept to a robust, scalable application. The final model's test accuracy of 99.1% underscores the effectiveness of the chosen methodology and data augmentation techniques. This work serves as a strong foundation for future enhancements, including the integration of more advanced sensor data like thermal imaging and deployment on edge devices for real-world use.

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