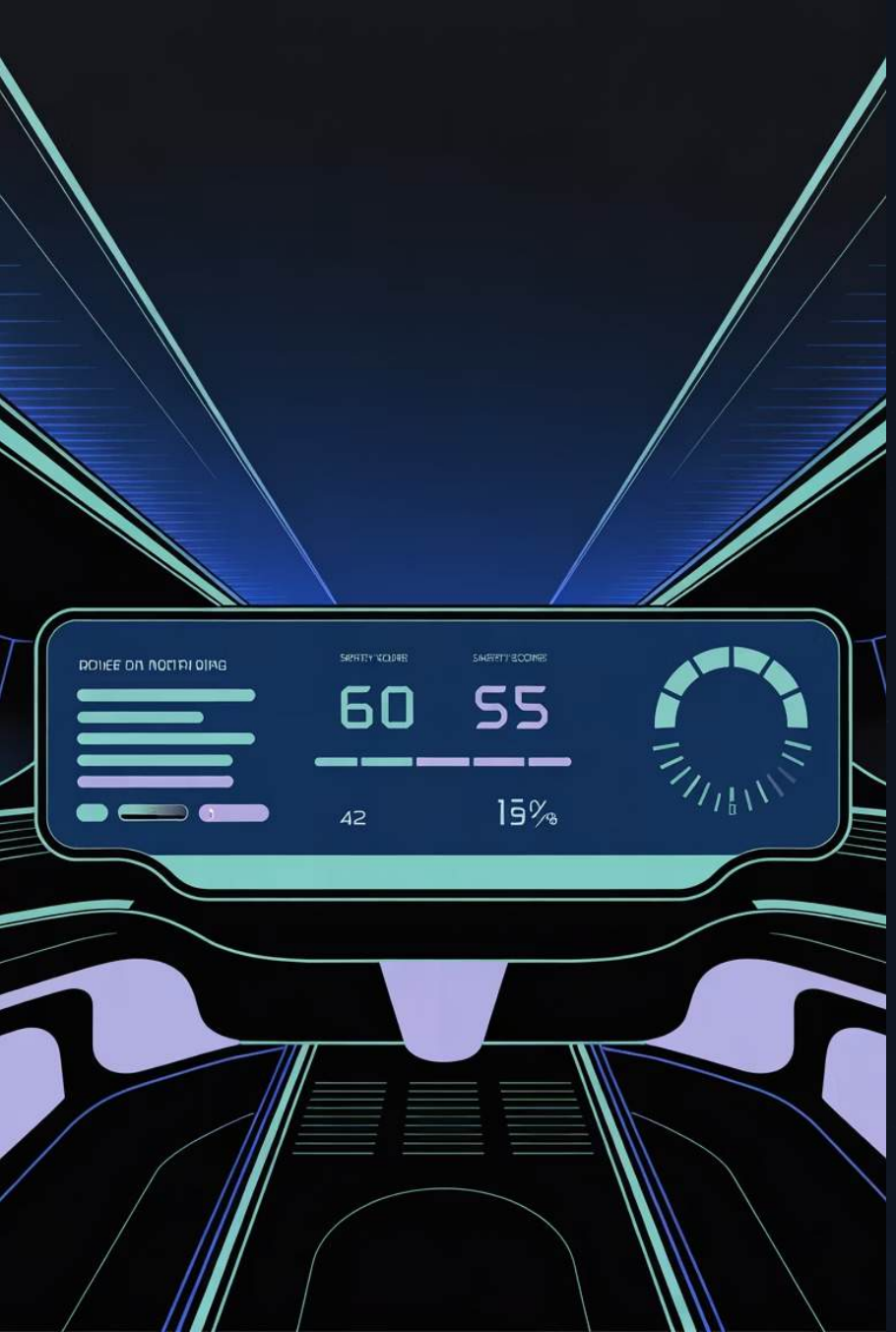


DRIVEGUARD AI: Revolutionizing Road Safety

DriveGuard AI is an **AI-powered dashcam analysis platform** that uses computer vision and deep learning to detect risky driving, identify safety violations, and calculate performance scores.

Group Number: 3

Members:

Jatin Jatin (A003)

Aman Jain (A010)

Alric D'Souza (A050)

The Growing Road Safety Crisis

1.35M Annual Road Deaths

Global fatalities, with 90% caused by human error (WHO, 2023).

3% GDP Cost

Road traffic crashes cost most countries 3% of their GDP.

Critical Gap

Fleets & insurers lack granular video evidence.

In India, 70% of 400,000+ annual accidents involve commercial vehicles, highlighting insufficient driver training and lack of real-time visibility for fleet managers.

Target Groups and Value Proposition

Commercial Fleets

Need real-time monitoring, objective driver scoring, and evidence collection. Helps in accident costs and lower insurance premiums.

Individual Drivers

Seek personalized feedback, skill improvement, and objective data to prove safe driving for potential insurance discounts.

Insurance Companies

Require objective data for Usage-Based Insurance (UBI), risk profiling, and claims verification to detect fraud.

Whitespace: The Gap in Existing Solutions

Identified Gaps

1. **GPS Dependency:** Unreliable or unavailable in critical environments.
2. **Video Analytics Complexity:** Proprietary, expensive, and hardware-intensive.
3. **Opaque Scoring:** Driver scores lack objective evidence or actionable feedback.
4. **Lack of Multi-Tenant** Architecture: Inflexible solutions for diverse client needs.

DriveGuard AI's Contribution

Video to Driver Score: AI transforms dashcam footage into objective driver performance metrics.

Events to Evidence: Automatically links driving events to corresponding video for irrefutable proof.

Scalable by Design: Multi-tenant, hardware-agnostic architecture supports all client types.

Literature Review & Comparative Analysis

Author / Source	Focus Area	Contribution to DriveGuard AI
Ohn-Bar & Trivedi (2016)	Vision-based driver monitoring	Informed object and gesture detection
Doshi & Trivedi (2010)	Attention & intent estimation	Inspired temporal context modeling
Jain et al. (2016)	Sequential modeling (RNNs)	Influenced event continuity tracking
Ultralytics YOLOv8 (2024)	Real-time detection benchmark	Used for all visual detections
WHO, NHTSA Reports	Global road safety data	Motivated need for automated analytics

Comparative Insight:
While prior research focuses on specific detection or prediction aspects, DriveGuard AI integrates **detection**, **event extraction**, **scoring**, and **explainable visualization**.

Technology Stack

Full-Stack Architecture Overview

Our stack is designed for performance, maintainability, and GPU-accelerated processing.

Frontend

React + TypeScript + Vite UI

Backend API

Node.js + Express + Multer

AI Analysis

Python, PyTorch, YOLOv8, OpenCV

The Node.js backend uses a non-blocking I/O model and **Child Processes** to spawn the Python AI engine, ensuring the API remains responsive during long video analyses.

Frontend & Backend Rationale

Frontend: Speed & Accessibility

React + TypeScript

Component-based architecture with static typing for reduced runtime errors.

Vite + Tailwind CSS

Lightning-fast development server and utility-first styling for rapid UI development.

Recharts + Radix UI

Interactive data visualization and accessible, customizable UI components.

Backend: Performance & I/O

Node.js + Express

Non-blocking I/O for handling multiple concurrent file uploads efficiently.

Multer

Robust middleware for handling video file uploads (up to 500MB limit).

Child Process

Enables asynchronous execution of the Python AI engine in the background.

AI/ML Engine: Optimized for Speed

We leverage industry-leading libraries optimized for GPU acceleration to minimize processing time.

Python 3.8+

The standard language for AI/ML, providing a rich ecosystem of scientific libraries.

OpenCV

Used for core computer vision tasks: video reading, color space conversion, and optical flow.

PyTorch 2.0+

Provides native GPU acceleration (CUDA/MPS) for 10x faster model inference.

YOLOv8n

Chosen for its balance of accuracy (37.3% mAP) and speed (80 FPS), crucial for real-time video analysis.

Performance Achieved: Analysis time for a 5-minute video is **8 minutes** (on Apple MPS), meeting our target of under 10 minutes.

Research-Backed Innovation: Multi-Modal Analysis

DriveGuard AI fills the gap by fusing advanced computer vision techniques to provide a unified, comprehensive analysis.

Proximity Detection

Uses **YOLOv8** for object detection combined with custom depth estimation based on bounding box geometry.

Speed Estimation

Fuses **Optical Flow** (Farnebäck, 2003) and feature tracking for robust speed calculation (achieving **±7 km/h** accuracy).

Traffic Compliance

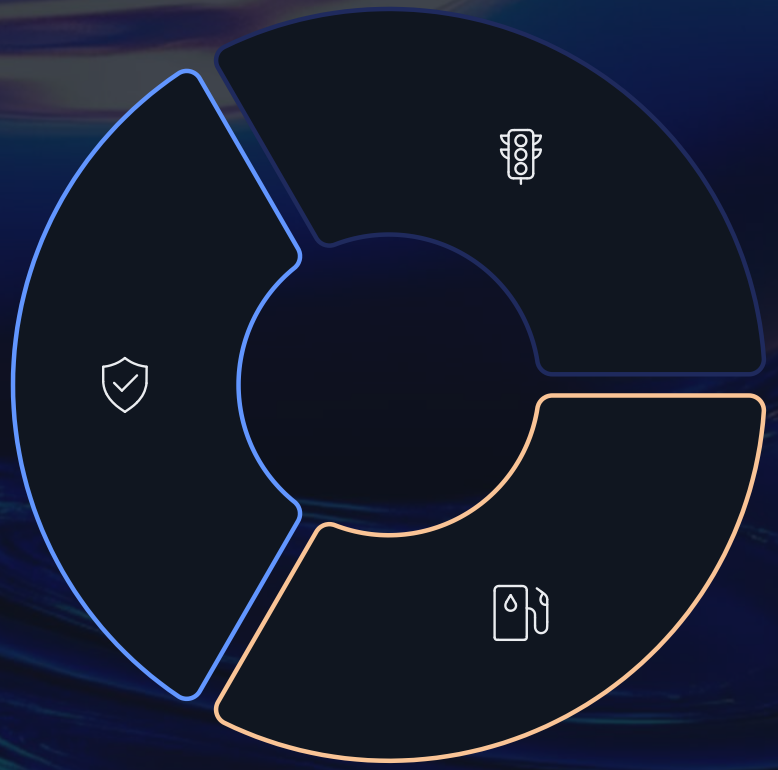
Utilizes **HSV Color Space** and temporal validation for 94% accurate traffic light and bus lane violation detection.

The Actionable Scoring System

We use a weighted scoring algorithm aligned with insurance industry standards to provide clear, actionable feedback.

Safety Score (50%)

Focuses on close encounters and collision avoidance metrics.



Compliance Score (30%)

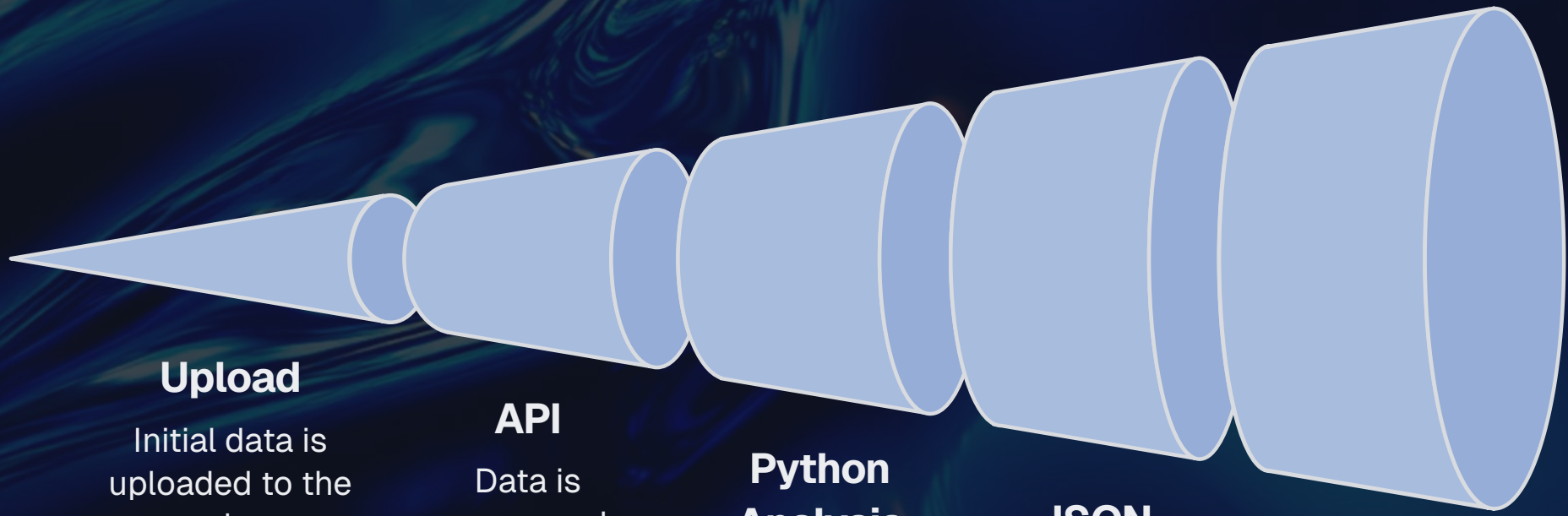
Measures adherence to traffic laws and lane discipline.

Efficiency Score (20%)

Evaluates smooth driving, minimizing aggressive lane changes and braking.

The system provides **Explainable AI** with exact timestamps and annotated frames for every incident, enabling targeted driver training.

Workflow:



Upload

Initial data is uploaded to the system.

API

Data is processed through the API.

Python Analysis

Scripts perform in-depth data analysis.

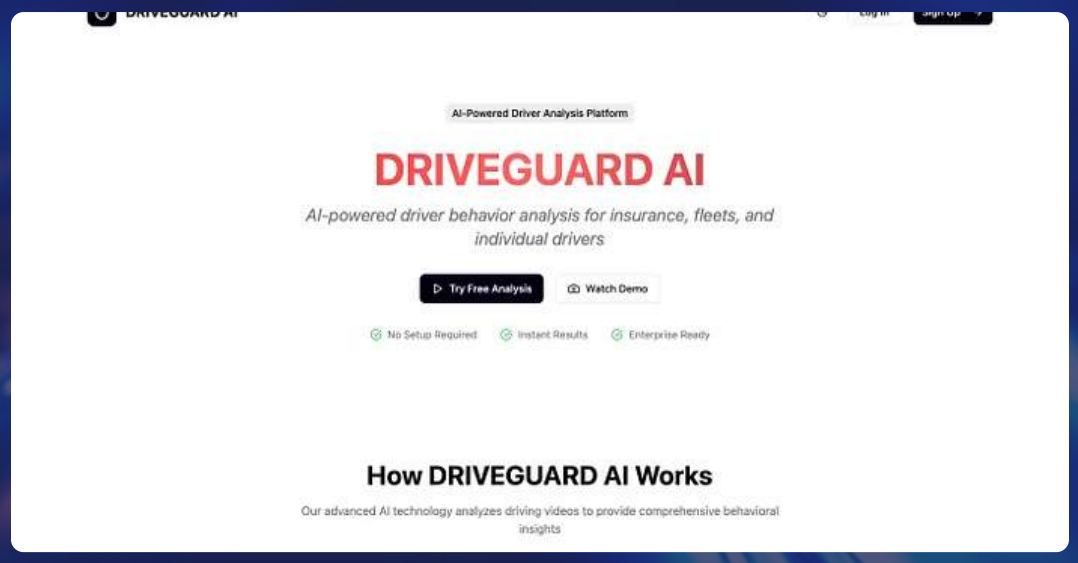
JSON Output

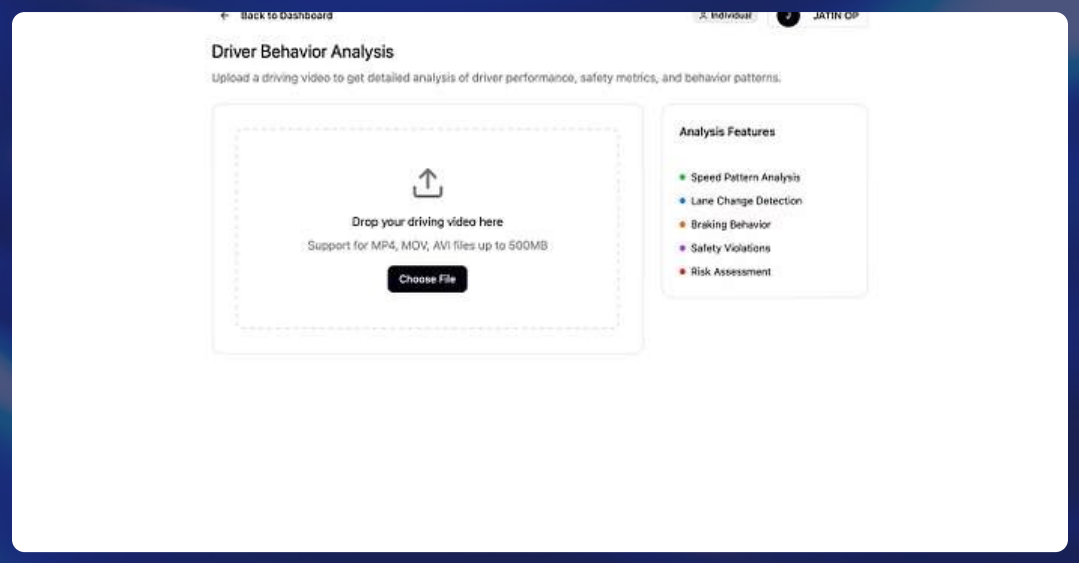
Analysis results are formatted as JSON.

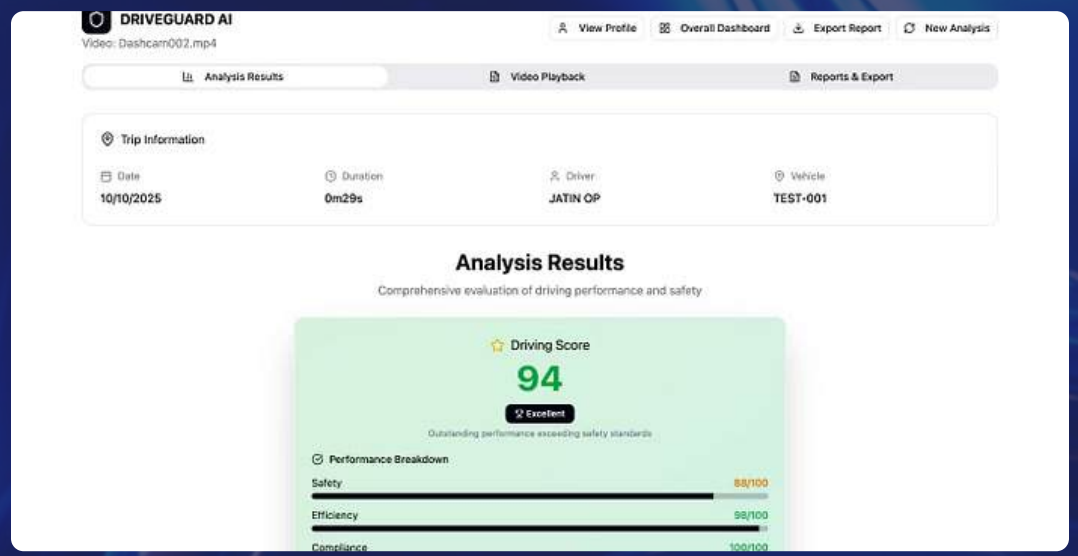
Dashboard Visualization

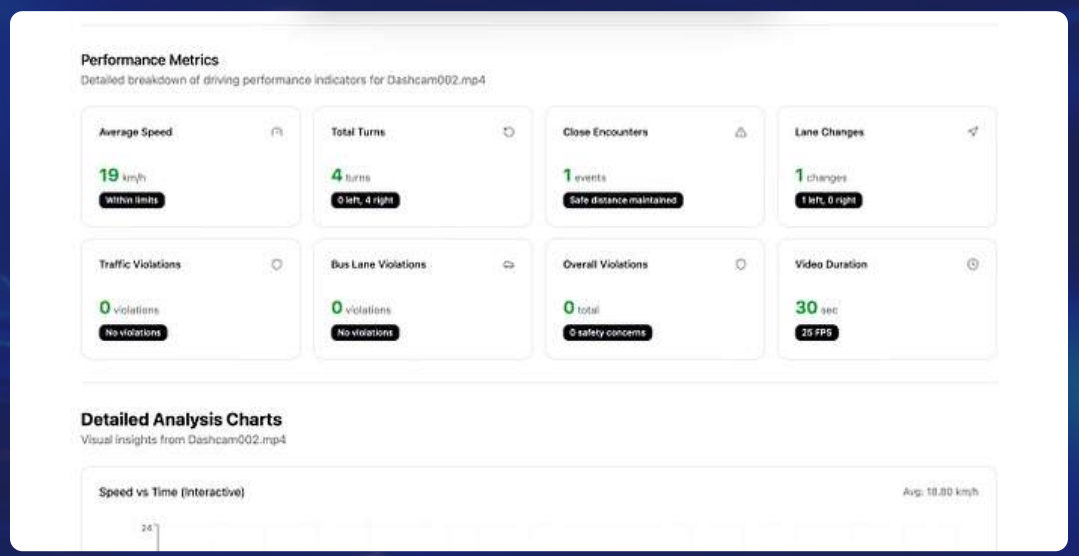
Final data is presented on a dashboard.

Platform UI

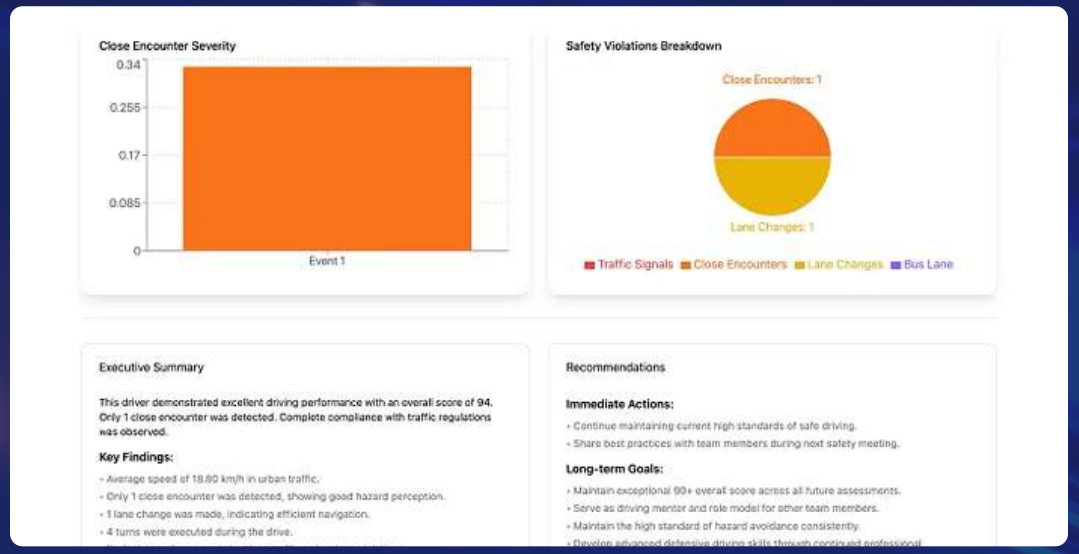

AI-Powered Driver Analysis Platform
DRIVEGUARD AI
AI-powered driver behavior analysis for insurance, fleets, and individual drivers
Try Free Analysis
Watch Demo
No Setup Required
Instant Results
Enterprise Ready
How DRIVEGUARD AI Works
Our advanced AI technology analyzes driving videos to provide comprehensive behavioral insights

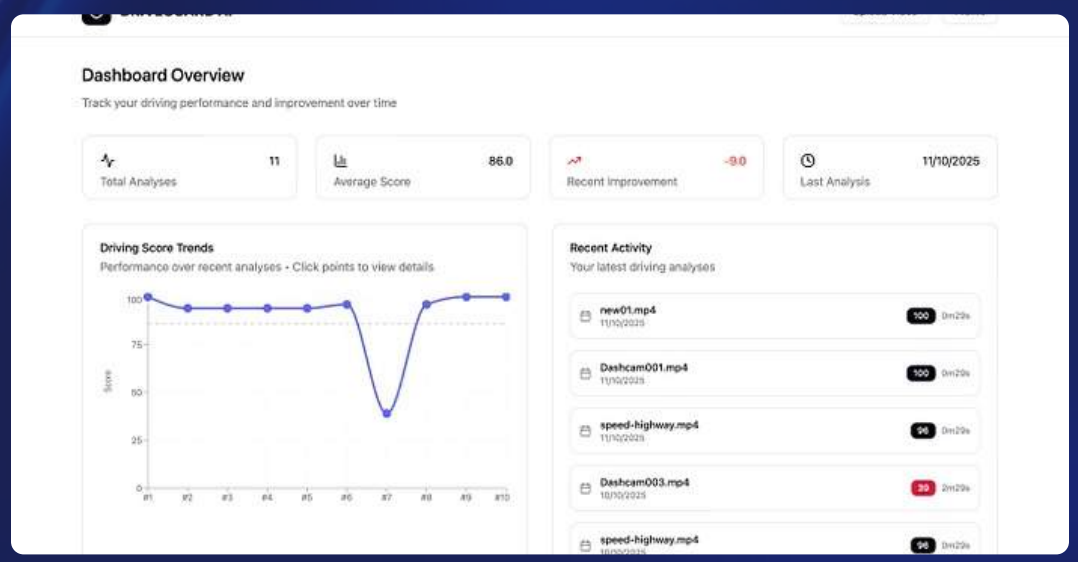

Driver Behavior Analysis
Upload a driving video to get detailed analysis of driver performance, safety metrics, and behavior patterns.
Drop your driving video here
Support for MP4, MOV, AVI files up to 500MB
Choose File
Analysis Features
Speed Pattern Analysis
Lane Change Detection
Braking Behavior
Safety Violations
Risk Assessment

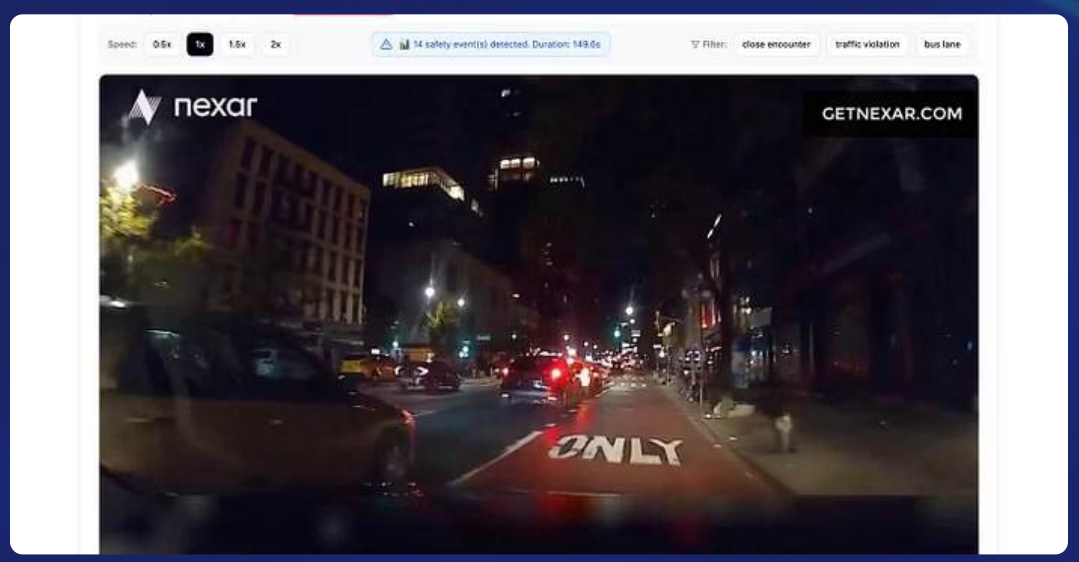

DRIVEGUARD AI
Video: Dashcam002.mp4
View Profile
Overall Dashboard
Export Report
New Analysis
Analysis Results
Video Playback
Reports & Export
Trip Information
Date
10/10/2025
Duration
0m29s
Driver
JATIN OP
Vehicle
TEST-001
Analysis Results
Comprehensive evaluation of driving performance and safety
Driving Score
94
Excellent
Outstanding performance exceeding safety standards
Performance Breakdown
Safety
88/100
Efficiency
98/100
Compliance
100/100


Performance Metrics
Detailed breakdown of driving performance indicators for Dashcam002.mp4
Average Speed
19 km/h
Within limits
Total Turns
4 turns
0 left, 4 right
Close Encounters
1 events
Safe distance maintained
Lane Changes
1 changes
1 left, 0 right
Traffic Violations
0 violations
No violations
Bus Lane Violations
0 violations
No violations
Overall Violations
0 total
0 safety concerns
Video Duration
30 sec
25 FPS
Detailed Analysis Charts
Visual insights from Dashcam002.mp4
Speed vs Time (interactive)
Avg: 18.80 km/h


Speed vs Time (interactive)
Avg: 18.80 km/h
Speed (km/h)
Time (MM:SS)
Speed Trend
Close Encounter
Traffic Violation
20.5
Max Speed (km/h)
18.8
Avg Speed (km/h)
1
Safety Events
Close Encounter Severity
Safety Violations Breakdown


Close Encounter Severity
Event 1
Safety Violations Breakdown
Close Encounters: 1
Lane Changes: 1
Traffic Signals
Close Encounters
Lane Changes
Bus Lane
Executive Summary
This driver demonstrated excellent driving performance with an overall score of 94. Only 1 close encounter was detected. Complete compliance with traffic regulations was observed.
Key Findings:
Recommendations
Immediate Actions:
Continue maintaining current high standards of safe driving.
Share best practices with team members during next safety meeting.
Long-term Goals:
Maintain exceptional 90+ overall score across all future assessments.
Serve as driving mentor and role model for other team members.
Maintain the high standard of hazard avoidance consistently.


Dashboard Overview
Track your driving performance and improvement over time
Total Analyses
11
Average Score
86.0
Recent Improvement
-9.0
Last Analysis
11/10/2025
Driving Score Trends
Performance over recent analyses - Click points to view details
Recent Activity
Your latest driving analyses
new01.mp4
Dashcam001.mp4
speed-highway.mp4
Dashcam003.mp4
speed-highway.mp4


Speed:
0.5x
1x
1.5x
2x
14 safety event(s) detected. Duration: 149.0s
Filter:
close encounter
traffic violation
bus lane
nexar
GETNEXAR.COM

Features Implemented

- Video upload (MP4) with client & server validation.
- YOLOv8-based object detection and tracker integration.
- Close-encounter detection with distance estimation and TTC calculation.
- Traffic-signal detection & red-light violation detection (YOLO + HSV color verification).
- Lane-change and turn detection (optical flow + feature tracking).
- Bus-lane violation detection (ROI-based red-lane detection).
- Per-trip scoring: safety, compliance, efficiency, overall score (weighted).
- JSON export of full analysis (metadata + events + scores).
- Interactive web dashboard: KPIs, speed/time charts, scrubbable player with event markers.
- Export options: PDF report generation (reportlab suggested), CSV export.
- User & org context persisted in local JSON (seeded dev accounts).

Code Structure & Quality Tools

Code Structure Highlights

Separation of concerns: frontend/ (UI), backend/ (API & orchestration), backend/analysis/ (Python CV pipeline)

Python modules separated by task: detection.py, tracking.py, distance_estimation.py, scoring.py, reporting.py

JSON schema for analysis results with versioning (to enable forward/back compat)

Code Quality & Dev Tooling

ESLint + Prettier

For frontend JS/TS linting & formatting

black + ruff

For Python formatting & linting

Unit tests

For pure functions in Python (scoring, TTC calc) using pytest (start with 30–40% coverage)

TypeScript types

For critical frontend data models (AnalysisResult, Event, Score)

Non-functional Requirements Achieved

Our architecture design and implementation prioritize critical non-functional aspects, ensuring a robust and efficient solution.

Performance

GPU acceleration via MPS (3–5× faster) and optimized frame sampling for rapid video analysis.

Reliability

JSON caching, graceful error handling, and comprehensive progress tracking ensure data integrity and system stability.

Scalability

Current sequential processing, with a clear roadmap for future distributed queue integration to handle increased load.

Usability

Responsive UI, clear progress indicators, and intuitive result visualization enhance user experience.

Security

Robust file validation and unique filename generation mitigate common security vulnerabilities.

Portability

Developed for macOS (MPS) with built-in support for CUDA deployment on Linux, ensuring broad platform compatibility.

Development Approach & Process

Our development strategy emphasizes agility, early validation, and robust quality assurance to build DriveGuard AI efficiently and effectively.

Iterative, User-First Methodology

Minimal UI

Build the foundational user interface to define core interaction flows.

Minimal APIs

Develop essential backend services to support the initial UI functionality.

Real Analysis

Execute actual video analysis on sample data for early validation.

UX Polish

Refine the user experience based on early feedback and iterative testing.

Key Principles

Agile Sprints

Short 1–2 week cycles focused on delivering a functioning end-to-end flow in each sprint (upload → analysis → display).

Documentation-First

Key analysis behaviors (event definitions, scoring rules) documented early to streamline testing and ensure reproducibility.

Defensive Engineering

Incorporates LocalStorage fallback, seeded test accounts, and JSON schema validation for system resilience and stability.

Addressing Development Challenges

During development, we encountered several technical hurdles. Our solutions demonstrate robust engineering and proactive problem-solving to ensure system reliability and user experience.

Challenge	Resolution
Test accounts not persisting	Seeded JSON DB & sync persistence
Cached analysis data	Invalidation logic & hard refresh
Invalid timestamps	JSON correction & video clamping
GPU incompatibility	Standardized MPS, CUDA optional
Multiple logs	Unified active log, doc updates
Long processing	Frame sampling & progress streaming

Current Limitations & Future Considerations

While DriveGuard AI demonstrates significant capabilities, we acknowledge key areas for improvement to ensure production readiness and expanded functionality.

Sequential Processing

Currently, analysis runs on a single worker, lacking distributed queuing and horizontal scaling for high throughput.

Storage & Persistence

File-based storage is not production-ready; a robust database and object storage solution are critical for reliability.

Model Edge Cases

Detection reliability can decrease with occlusions, extreme night lighting, and non-standard traffic elements.

Limited Testing

A comprehensive evaluation on large, labeled datasets is still pending to validate overall performance.

Concurrency & Rate Limiting

Future development requires throttling and worker autoscaling to handle production-level concurrent loads.

Future Scope

Our roadmap includes ambitious developments to evolve DriveGuard AI into a comprehensive, real-time, and highly scalable road safety solution.

Robust Data Infrastructure

Migrate to PostgreSQL/MongoDB for transactional data and S3 for scalable video storage.

Parallel Processing & Queues

Introduce distributed queue systems (Bull/Celery) for parallel analysis and enhanced throughput.

Real-Time Stream Analysis

Enable live analysis of dashcam footage for immediate incident detection and alerts.

Mobile Application

Launch dedicated mobile applications.

OBD-II Sensor Integration

Integrate with vehicle OBD-II sensors for enriched multimodal analytics and deeper insights.

Continuous Model Enhancement

Enhance AI model accuracy through larger, diverse datasets and continuous retraining cycles.

Platform Video

Google Drive

DRIVEGUARD AI DEMO – Google Drive

DriveGuardAI analyzes dashcam footage to provide comprehensive driving safety scores, behavior insights, and actionable recommendations.