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Autonomous obstacle avoidance using computer vision for electric auto

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Abstract
Electric Vehicles (EVs) are rapidly transforming the global transportation landscape due to their environmental advantages, improved energy efficiency, and reduced dependence on fossil fuels. However, as EV adoption increases, ensuring vehicle safety through intelligent automation becomes increasingly important. Advanced Driver Assistance Systems (ADAS) play a critical role in improving vehicle safety by assisting drivers in detecting obstacles, maintaining proper lane discipline, and preventing potential accidents. This paper presents EV AUTO, a vision-based prototype designed to perform autonomous obstacle avoidance functions for electric vehicles. Unlike traditional safety systems that depend on expensive sensors such as LiDAR or basic proximity sensors like ultrasonic modules, the proposed system uses computer vision and deep learning techniques to interpret the surrounding road environment in real time. The system employs OpenCV for image processing and a Convolutional Neural Network (CNN) model to detect lane boundaries and identify obstacles such as vehicles, pedestrians, or road hazards. The camera module captures continuous road images, which are processed using image preprocessing techniques including noise reduction, edge detection, and feature extraction. The CNN model analyzes these processed frames to identify lane markings and classify obstacles in the vehicle's path. Based on the detected information, the system automatically generates control commands that adjust the vehicle’s steering and speed to maintain lane alignment and avoid potential collisions. Simulation-based experiments demonstrate that vision-based automation significantly improves system reliability and decision-making capability compared to rule-based sensor systems. Furthermore, the proposed solution maintains a low-cost architecture, making it suitable for integration into mass-market electric vehicles rather than being restricted to high-end automotive platforms. The EV AUTO system highlights how artificial intelligence, computer vision, and embedded systems can work together to create intelligent safety solutions for next-generation electric mobility.

Keywords: Electric Vehicle, Autonomous Driving, Computer Vision, CNN, Lane Keeping System, Obstacle Avoidance, OpenCV, Intelligent Transportation Systems

Introduction

A. Background

The global transportation sector is undergoing a significant transformation due to increasing environmental concerns, rapid urbanization, and the urgent need to reduce greenhouse gas emissions. Electric vehicles have emerged as a promising solution to these challenges because they produce zero tailpipe emissions and offer higher energy efficiency compared to conventional internal combustion engine vehicles. While electric vehicles contribute to environmental sustainability, improving road safety remains an equally important objective. According to international road safety reports, millions of accidents occur annually, resulting in significant economic losses and human casualties. A large proportion of these accidents are caused by human errors, such as driver distraction, fatigue, delayed reaction time, and poor decision making. To address these issues, modern automotive systems are increasingly incorporating intelligent technologies known as Advanced Driver Assistance Systems (ADAS). These systems assist drivers by providing automated support for tasks such as lane tracking, obstacle detection, collision avoidance, and adaptive cruise control. Autonomous driving technology is gradually evolving from basic driver assistance to full vehicle automation. Among the essential components of autonomous driving systems are lane-keeping assistance and obstacle avoidance, which ensure safe vehicle navigation on busy roads.

B. Motivation
Human error is responsible for nearly 90% of road accidents worldwide. Factors such as inattentive driving, poor visibility, and delayed reaction time contribute significantly to these incidents. Autonomous driving technologies aim to reduce these risks by enabling vehicles to perceive their environment and respond automatically to potential hazards.

Lane keeping systems help vehicles remain within the designated road lane, preventing unintentional lane departures that may lead to accidents. Obstacle avoidance systems detect objects on the road and initiate corrective actions such as braking or steering adjustments.

Traditional implementations of these systems often rely on expensive sensors such as LiDAR, radar, or multiple camera arrays, which significantly increase vehicle cost. Consequently, such technologies are typically available only in luxury vehicles.

This project is motivated by the need to develop a cost-effective and intelligent safety system that can be integrated into affordable electric vehicles while maintaining high reliability and accuracy.

C. Problem Statement
Although modern ADAS technologies offer significant safety benefits, their widespread adoption is limited due to high hardware costs and complex system requirements. Many existing systems depend on specialized sensors and proprietary hardware, making them unsuitable for low-cost electric vehicle platforms.

Additionally, rule-based systems that rely solely on ultrasonic or infrared sensors often provide limited environmental understanding, as they can only detect objects within a short distance and lack contextual awareness of road conditions.

Therefore, there is a strong need to develop an **affordable, intelligent, and scalable safety system** that uses advanced perception techniques while minimizing hardware complexity. The proposed EV AUTO system addresses this challenge by using **computer vision and deep learning algorithms** to interpret the road environment using a single camera sensor.

Literature Review
The development of autonomous vehicle technologies has been widely explored in recent research. This section reviews several key areas relevant to the EV AUTO system.

1. Vision-Based Lane Keeping Systems (2024)

Recent studies have demonstrated that computer vision techniques can effectively detect lane boundaries using edge detection, perspective transformation, and deep learning models. Vision-based systems provide better adaptability to varying road conditions compared to traditional sensor-based approaches.

2. Machine Vision for Obstacle Detection (2024)

Machine vision algorithms are capable of identifying various road objects such as vehicles, pedestrians, traffic signs, and barriers. These systems use convolutional neural networks to classify objects in real time, enabling safer navigation.

3. YOLOv5 Object Detection Architectures (2024)

YOLO (You Only Look Once) is a widely used real-time object detection algorithm. YOLOv5 improves detection speed and accuracy, making it suitable for autonomous vehicle applications where rapid decision making is essential.

4. Deep Reinforcement Learning for Autonomous Navigation (2025)

Deep reinforcement learning has been applied to autonomous driving systems to allow vehicles to learn optimal navigation strategies through simulated training environments.

5. Comprehensive Lane Detection Reviews (2026)

Recent survey papers summarize various lane detection techniques including traditional image processing methods, machine learning models, and hybrid approaches.

6. Ultrasonic vs Vision-Based Systems

Ultrasonic sensors are effective for short-range obstacle detection but cannot provide detailed environmental information. Vision-based systems offer richer perception capabilities by analyzing the entire visual scene.

7. Edge Computing in Electric Vehicles

Running AI models on embedded hardware requires efficient processing architectures. Edge computing allows real-time data processing directly within the vehicle without relying on cloud services.

8. Simulation-to-Real Gap

AI models often perform differently in simulation environments compared to real-world conditions. Addressing this gap is crucial for successful deployment of autonomous systems.

9. Environmental Sensitivity

Factors such as rain, fog, shadows, or faded lane markings can affect the accuracy of computer vision algorithms. Robust models must be trained to handle such variations.

10. Cost-Effective Prototyping

Open-source frameworks such as OpenCV, TensorFlow, and PyTorch enable researchers to develop advanced autonomous vehicle prototypes without expensive proprietary tools.

Methodology
A. System Architecture
The EV AUTO system follows a hierarchical processing pipeline consisting of several stages.

1. Image Acquisition

A high-resolution camera mounted on the vehicle continuously captures video frames of the road environment. These frames serve as the primary input for the perception system.

2. Image Preprocessing

The captured frames are processed using OpenCV image processing techniques, including:

- Noise reduction using Gaussian filtering
- Edge detection using Canny algorithms
- Region-of-interest selection
- Contrast enhancement for clearer lane visibility

3. Deep Learning Model

A Convolutional Neural Network (CNN) analyzes the processed images to detect lane boundaries and classify potential obstacles in the vehicle's path.

The model extracts visual features such as edges, shapes, and patterns to identify lane markings and objects with high accuracy.

B. Control Logic
The system converts perception outputs into vehicle control actions.

- **Lane Correction**
  When the system detects that the vehicle is drifting

away from the center of the lane, it automatically adjusts motor speeds to steer the vehicle back into the correct position.

- **Braking and Obstacle Avoidance**
  If an obstacle is detected ahead, the system generates commands to slow down, stop, or recalculate a safe path to avoid collision.

Hardware and Software Integration

- **Technical Feasibility**
  The EV AUTO prototype combines embedded hardware and AI software frameworks.
- **Microcontroller / Embedded Processor**
  Acts as the control unit responsible for receiving processed data and controlling vehicle movement.
- **Camera Module**
  Serves as the primary environmental sensor capturing real-time road images.
- **Motor Driver**
  Controls the speed and direction of the motors based on system commands.
- **Simulation Environment**
  The system is first tested in simulation platforms such as CARLA or PyGame, which allow safe testing of autonomous driving algorithms before real-world implementation.

Results and Analysis

A. Comparative Study

Feature	Existing Systems	EV AUTO (Proposed)
Sensor Type	Ultrasonic / Infrared	High-Resolution Camera
Control Logic	Rule-Based	AI-Driven CNN
Performance	Limited obstacle detection	Detailed environmental perception
Cost	High due to sensor arrays	Low cost AI-based solution

B. Experimental Observations
Simulation testing demonstrated the following outcomes:

- High accuracy in lane detection under normal lighting conditions
- Reliable obstacle detection for vehicles and pedestrians
- Fast response time suitable for real-time vehicle control
- Sensitivity to poor lane markings and extreme lighting conditions

These results indicate that vision-based perception systems provide a powerful alternative to traditional sensor-based approaches.

Discussion
Advantages
The EV Auto system offers several advantages:

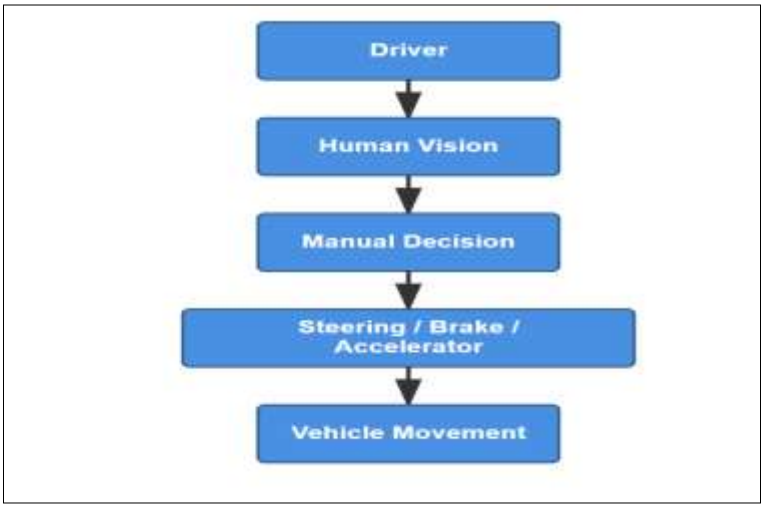
- High detection accuracy using deep learning models
- Improved road environment understanding compared to simple sensors
- Scalable architecture suitable for different EV platforms
- Lower hardware cost due to reduced sensor requirements
- Compatibility with open-source AI frameworks

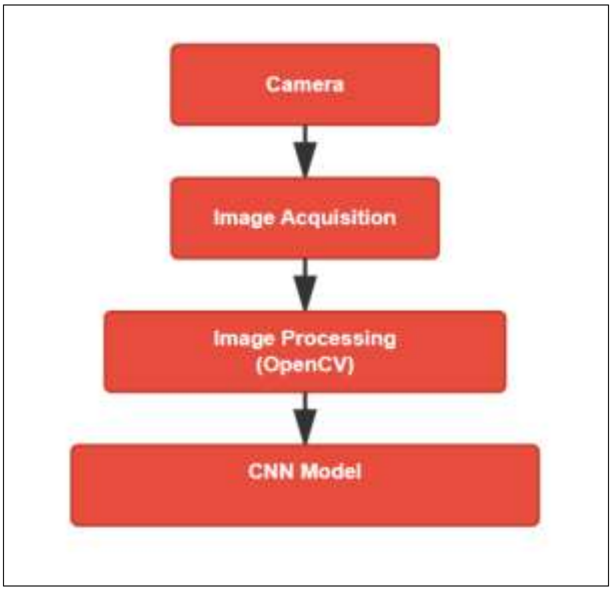
Challenges
Despite its advantages, the system faces certain challenges:

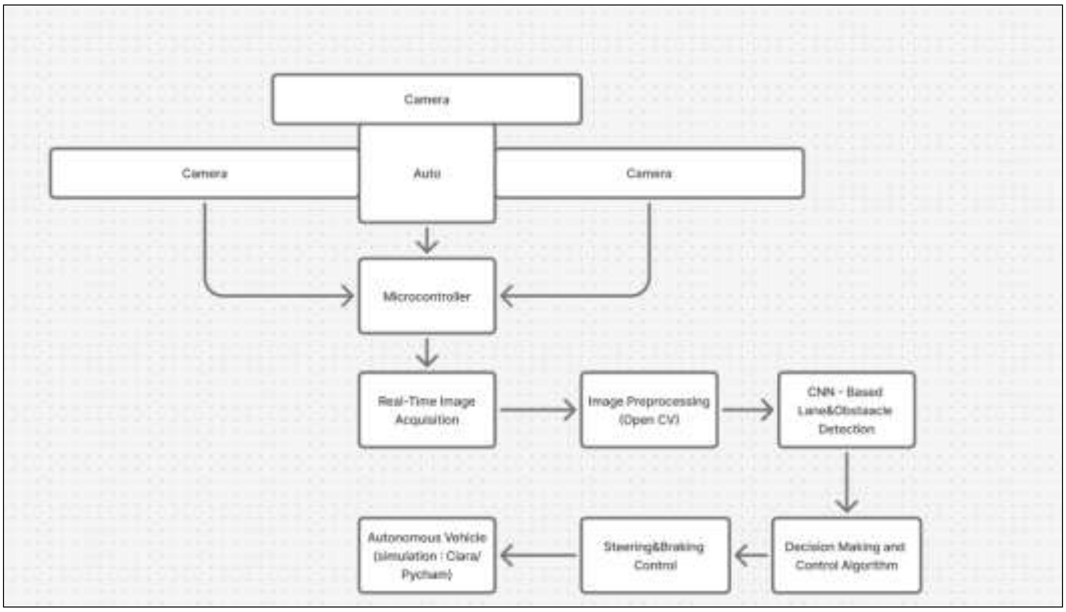
- High computational requirements for running CNN models in real time
- Limited depth perception when using a single camera
- Reduced performance in poor weather conditions or faded lane markings

Future improvements can address these limitations by integrating additional sensors such as LiDAR or stereo cameras.

Conclusion and Future Work
The EV AUTO project demonstrates the feasibility of a vision-based autonomous safety system for electric vehicles. By combining computer vision techniques, deep learning models, and embedded control systems, the proposed approach successfully performs lane keeping and obstacle avoidance tasks.
The use of low-cost hardware and open-source software frameworks makes the system suitable for widespread adoption in affordable electric vehicles. Simulation results confirm that the system can effectively detect road lanes and obstacles while maintaining reliable vehicle control.
Future work will focus on improving system robustness by integrating additional sensors such as LiDAR, radar, and GPS modules. Advanced machine learning algorithms and reinforcement learning techniques may also be implemented to enable fully autonomous navigation in complex traffic environments.







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