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Design and Prototyping of Advanced Driver Assistance System

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Abstract
This article introduces a practical approach to road lane and object detection for an autonomous car prototype, leveraging OpenCV and Python. The lane detection system applies pre-processing techniques like edge detection and Hough Transform to accurately identify lane boundaries in real-time. For object detection, the model integrates YOLO via OpenCV's DNN module to detect vehicles, pedestrians, and other obstacles. The system is powered by an Arduino-based motor control setup with a laptop handling image processing instead of a Raspberry Pi. Experimental tests demonstrate its ability to function under varying road and lighting conditions, proving its potential for real-world driver assistance and autonomous navigation. Future enhancements include integrating LiDAR/Radar for improved obstacle detection and transitioning to deep learning-based lane tracking.

Keywords: Lane Detection; Object Detection; OpenCV & YOLO

INTRODUCTION

With the rapid advancements in autonomous vehicles and Advanced Driver-Assistance Systems (ADAS), the demand for accurate road lane and object detection technologies has significantly increased. Ensuring that vehicles stay within their designated lanes and effectively detecting obstacles like other vehicles and pedestrians are essential for improving road safety and developing reliable autonomous navigation systems. Lane discipline remains a major challenge, contributing to road accidents that result in severe injuries and fatalities.

This project focuses on developing an autonomous car prototype that integrates lane detection, object detection, and lane-based motor control. The system utilizes OpenCV for real-time image processing and YOLO (You Only Look Once) for object detection, running on a laptop instead of a Raspberry Pi. Lane detection relies on edge detection and Hough Transform techniques, while object detection allows the system to identify vehicles, pedestrians, and other obstacles efficiently. An Arduino-based motor control system processes these inputs to ensure accurate vehicle movement.

By combining computer vision and embedded systems, this project demonstrates how engineering solutions can enhance road safety. Future improvements, such as integrating LiDAR/Radar sensors and exploring deep learning-based lane tracking, can further refine the system's accuracy and reliability.

This work highlights the critical role of mechanical engineers in addressing real-world transportation challenges and shaping the future of autonomous vehicle technology.

RELETED WORK

Many researchers have worked on improving lane and object detection systems for Indian roads, which are often complex and different from roads in other countries. Other researchers suggested creating datasets that show real Indian road conditions, since most available datasets are not suitable. Tools like Rob flow help make this easier by providing simple ways to label images, organize data, and keep track of changes.Researchers used a method called transfer learning. This means they took models that were already trained on general data and improved them using images from Indian roads. rob flow Universe supports this by giving access to ready-made models and letting users train them with their own data.

Agrawal and Mohan talked about how poor lane markings in India make detection difficult. They solved this by using data augmentation, which adds variations to the images like different lighting or weather. This helps the model work better in real-life situations. rob flow also offers these tools to improve training.

In our project, we applied similar methods. We used OpenCV for lane detection and YOLOv8 for object detection. The system runs on a laptop and controls motors using Arduino. Like in the previous research, our system was tested in real conditions and worked well. It can detect lanes, stop for obstacles, and even overtake when needed.All of these approaches help make driving safer and bring us closer to self-driving technology that works well on Indian roads.

METHODOLOGY

This section outlines the structured approach used to develop and test the autonomous car prototype, incorporating lane detection, object detection, and motor control. The system integrates OpenCV and YOLO for image processing, along with an Arduino-based motor control system. The prototype is designed to run on a laptop instead of a Raspberry Pi, ensuring efficient processing and real-time decision-making.

1. Prototype Design & Hardware Integration

Mechanical Design:

The vehicle's physical structure is designed using Catia V5 to accommodate key hardware components, ensuring stability and smooth operation. The chassis provides mounting points for the laptop camera, motors, and servo motor, with a sturdy build for reliable movement. Steering is controlled using an MG995 Servo Motor, while a 12V RS 555 Motor is used for forward and backward movement. The L298N Motor Driver regulates speed and direction, ensuring precise vehicle control.

A lightweight chassis was modelled using CAD software and fabricated via 3D printing with PLA 850 filament. The material was selected for its strength-to-weight ratio. The design included mounting provisions for:

- Servo motor (steering)
- DC motor (propulsion)
- Wheels
- USB camera

Chassis material:

- Material: PLA 850 (Polylactic Acid)
- ManufacturingMethod: 3D Printing (Fused Deposition Modelling - FDM)

Hardware Setup:
An Arduino Uno processes laptop data and controls motor functions.
A webcam camera captures real-time video for lane detection.
The motor system, powered by a 12V battery, ensures smooth propulsion.
Additional sensors like LiDAR/Radar may be integrated in future improvements for enhanced obstacle detection.
2. Data Processing & Algorithm Implementation
Computer Vision & AI Frameworks:
Lane Detection: The system employs OpenCV techniques such as Canny Edge Detection and Hough Transform to identify lane boundaries.
Object Detection: YOLO (via OpenCV DNN) enables real-time recognition of vehicles, pedestrians, and obstacles, ensuring safe navigation.
Sensor Data Processing:
The laptop processes live video input, detects lane markings, and determines vehicle positioning. Detected obstacles trigger appropriate steering and speed adjustments, with the Arduino executing motor commands accordingly.
3. Simulation
Before physical testing, simulations are performed to validate lane detection and object recognition capabilities. This helps fine-tune the system's accuracy before deployment.
The system was tested extensively in both virtual simulations and real-world environments. Feedback from these tests helped fine-tune the:

- Detection accuracy
- System responsiveness

4. Real-World Testing
The prototype is tested in different environments with varying lighting and road conditions to evaluate performance. Key parameters such as lane detection accuracy, response time, and object detection efficiency are measured to assess reliability.

5. Safety & Ethical Considerations
Any collected test data is anonymized and used strictly for performance analysis and improvement.
The testing phase prioritizes transparency, with clear documentation of system performance and limitations.
The use of open-source technologies like OpenCV and YOLO promotes accessibility and responsible innovation.

IMPLEMENTATION

The prototype combines hardware elements, image processing techniques, and motor control to enable autonomous vehicle navigation. The system is built to detect lanes and recognize obstacles in real-time while managing vehicle motion through an Arduino-based control setup.

1. Hardware Configuration

The hardware setup includes both electrical and mechanical parts, working together to achieve the goal of self-driving movement. The main components include:

- Chassis and steering mechanism*:* A stable chassis structure hold all the components, including an MG995 Servo Motor that adjusts the steering angle of the vehicle.
- Drive motor: A 12V RS555 DC motor, controlled by an L298N motor driver, powers the vehicle. The motor's speed and direction change based on the lane detection results.
- Camera and processing unit: A webcam is used to capture video, which is processed on a laptop for better performance. The laptop runs OpenCV for detecting lanes and YOLO for identifying objects.
- Power source: A 12V battery supplies the necessary power to the motors and the Arduino board.

2. Software Operation

The system's intelligence comes from computer vision, which processes video input and takes decisions based on what it detects.

- Lane detection:
  - The video feed from the camera is processed using OpenCV.
  - Canny edge detection is used to find the edges of the lane.
  - Using line detection methods, the system identifies the lane and the vehicle's position within it.
  - Based on the lane position, commands are sent to the servo motor to steer the vehicle accordingly.
- Object detection:
  - YOLO is used to recognize objects like people, vehicles, and traffic signs.
  - Depending on the position of the object, the system decides whether to stop, turn, or continue.
  - These decisions are then sent to the Arduino, which drives the motor and steering accordingly.

3. Motor and Movement Control

The Arduino Uno is responsible for controlling vehicle motion based on inputs from the detection modules:

- *Steering control*: The servo motor receives angle instructions to keep the vehicle aligned with the lane.
- *Speed adjustment:* The L298N motor driver manages the speed of the RS555 motor depending on detected obstacles or turns.
- *Direction handling:*The system dynamically switches between forward, backward, and turning motions to avoid obstacles and stay on track.

*4.*Testing and Performance Evaluation

- *Initial testing*: Algorithms were first validated using test scenarios to improve lane and object detection.
- *Field testing*: The prototype was tested in different lighting conditions and on various surfaces to check real-world performance.

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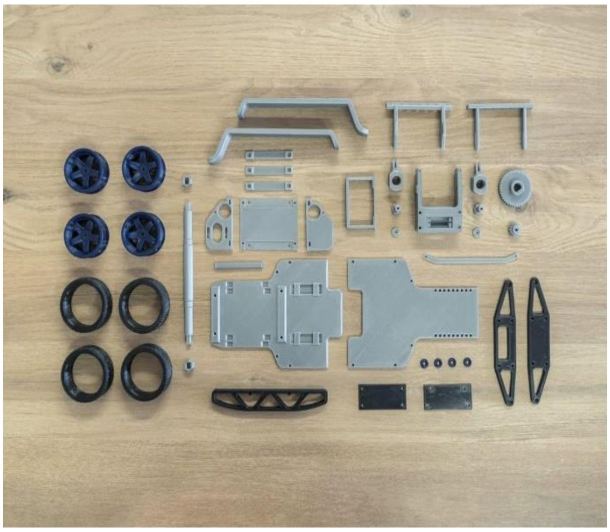
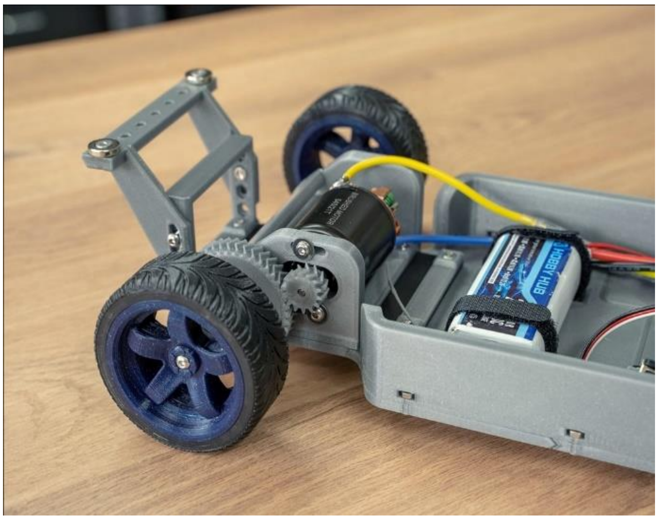
- *Evaluation criteria*: Parameters like detection success rate, reaction time, and overall system response were studied to fine-tune performance.

5.Scope for Improvement

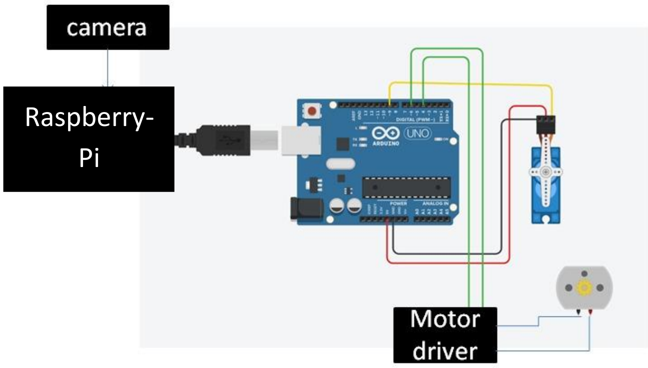
The system can be further enhanced with the following upgrades:

- Adding LiDAR or radar sensors to improve obstacle detection.
- Using advanced deep learning models for more reliable lane tracking.
- Replacing the laptop with a Raspberry Pi or other embedded board for a compact, portable setup.



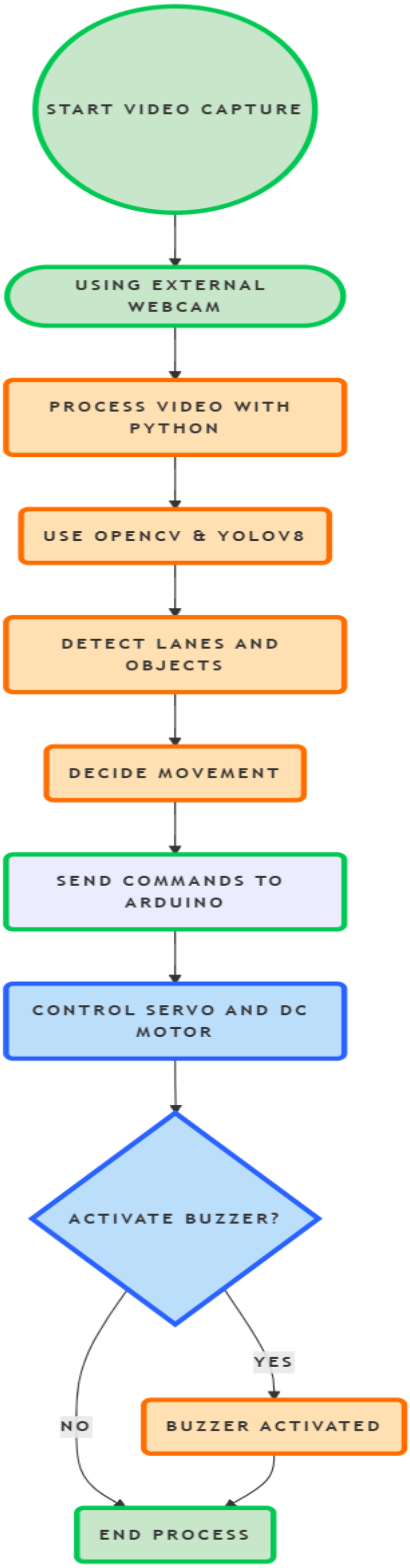


3D Printed Material: PLA 850 **Assembled Chassis**



Camera Mounting **System Electronics**

SYSTEM FLOW


START VIDEO CAPTURE
USING EXTERNAL WEBCAM
PROCESS VIDEO WITH PYTHON
USE OPENCV & YOLOV8
DETECT LANES AND OBJECTS
DECIDE MOVEMENT
SEND COMMANDS TO ARDUINO
CONTROL SERVO AND DC MOTOR
ACTIVATE BUZZER?
YES
NO
BUZZER ACTIVATED
END PROCESS

CONLUSION

This project successfully demonstrates the design and development of a low-cost, functional prototype of an Advanced Driver Assistance System (ADAS) using computer vision and embedded systems. By integrating OpenCV for lane detection and YOLOv8 for real-time object recognition, the system is capable of making intelligent decisions such as stopping, turning, and lane following. The use of an Arduino-based motor control unit enables accurate vehicle movement in response to visual input, while field testing under varied conditions confirmed the system's reliability and adaptability.

The overall results highlight the potential of combining software-based image processing with simple hardware to create an effective and scalable ADAS solution for Indian road environments. With future improvements like LiDAR integration, deep learning-based lane tracking, and deployment on portable hardware like a Raspberry Pi, this system can be made more efficient and ready for real-world applications in autonomous vehicles.

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