

Evolving ADAS Capabilities in India: A Step towards SAE Level 3

Nishigandha Vyawahare¹, Prof. Santosh Biradar², Krutika Ragad³, Aman Kanojia⁴, Swayam Chinche⁵

Assistant Professor, Dept. of Data Science, G.H. Raisoni College of Engineering and Management, Pune, India¹

Professor, Dept. of Data Science, G.H. Raisoni College of Engineering and Management, Pune, India²

Undergraduate Student Dept. of Data Science, G.H. Raisoni College of Engineering and Management, Pune, India³

Undergraduate Student Dept. of Data Science, G.H. Raisoni College of Engineering and Management, Pune, India⁴

Undergraduate Student Dept. of Data Science, G.H. Raisoni College of Engineering and Management, Pune, India⁵

ABSTRACT: The automotive industry is now working hard to achieve autopilot vehicles, with high-tech Advanced Driver Assistance Systems (ADAS). Nevertheless, the major obstacle to the popularization of such technologies in India is that ADAS focuses on organized roads in developed nations, whereas the traffic in India is anarchy and unpredictable because of the lack of suitable infrastructure and various road users. The paper provides the specific road map of developing Level 3 ADAS prototype with reference to the Indian road network. The proposed system will be the vision-based, centralized platform that will have the real time lanes, potholes and traffic sign detection system and drowsiness system of the driver. The methodology is based on a hybrid approach, which implies the combination of conventional computer vision algorithms, such as OpenCV, with modern deep learning AI models, such as YOLOv5 and Mask R-CNN. Individual models will be trained on modified datasets, collected in Indian roads. The final outcome should be a working and efficient prototype and a road map that can be used to accelerate the implementation of ADAS in India to enhance road safety and driving comfort.

KEYWORDS: Advanced Driver Assistance Systems (ADAS), SAE Level 3, Indian Traffic Scenarios, Computer Vision, Deep Learning, Pothole Detection

I. INTRODUCTION

This Advanced Driver Assistance systems (ADAS) have become widely used and developed, leading to a change in the global automotive industry. These systems go as far as basic notifications, and halfway control of the vehicle, and they are enhancing safety and comfort of drivers. ADAS market is expanding at a rapid pace and the global market size is estimated at USD 34.65 billion in the year 2024 and this is projected to increase to USD 66.56 in the year 2030. The reason of this growth is the utilization of ADAS in a larger number of cars and the increased awareness of people about safety. Other features of key ADAS functions, such as Automatic Emergency Braking (AEB) and Lane Departure Warning (LDW) are also being encouraged or mandated by governments. The technology that is useful in this advancement is a sophisticated piece of components in which sensors such as radar and LiDAR have the greatest market share as they are the key elements in active ADAS operations [1], [2].

Irrespective of this development around the world, it is hard to take ADAS to India. The rate of road accidents in India is one of the highest in the world, so the use of ADAS is a question of safety of the population. A survey conducted by Here Technologies revealed that 91 percent of the respondents would consider ADAS essential to road safety and that 82 percent of them would be willing to purchase a car equipped with ADAS. But such interest is contrasted with the low market penetration which is at 8.3 only in the first half 2025. This is mainly attributed to the fact that Indian roads are not much structured and with the combination of cars, rickshaws, and two-wheelers and some unforeseeable habits, such as a tendency to cut lanes and even to jaywalk. The key issue is that modern ADAS, which are intended to work on the organized roads, are regarded as not very reliable on the Indian roads with its unorganized traffic. In India, camera-based camera systems find it difficult to deal with faded lane markings, road signs that do not match, and many potholes. This underperformance results in a high number of false alarms and an overall reduction in functionality due to which consumer confidence is lost and adoption is slowed down [3], [4], [5].

This project will provide a solution to this issue by designing a Level 3 ADAS prototype that will suit the Indian road conditions. The system will be based on state-of-the-art computer vision and machine learning methods based on local data to be used to guarantee effective and real-time identification of key features on the road [6], [7].

The project will offer a technical guideline that could be used as blueprint of future research and development in India. The prototype will demonstrate that there is a possibility to implement advanced ADAS in unstructured roads, closing the technology and locality gap at the global level. The research will deliver a hands-on solution to guide the strategies of the industry and the policy of the people of India to fast track the intelligent transport and road safety in India [8].

II. LITERATURE REVIEW

The Advanced Driver Assistance Systems (ADAS) have been a popular subject of research in India, with some studies always reporting the major challenges. An example of this study conducted over IIT Madras concluded that the ADAS functions such as Lane Departure Warning and Adaptive Cruise Control are not effective in the unpredictable Indian driving environment. Problems at hand were unmarked lanes, abrupt crossing of pedestrians and common cutting of lanes by the two-wheelers and auto-rickshaws. On the same note, an AI-assisted pedestrian and obstacle detection NATRIP study detected false positives and erroneous system responses due to unpredictable human behavior and dense traffic on the roads meaning that vehicle density was high. A collaborative project to consider ADAS in aggressive driving patterns and unforeseen challenges such as stray animals was also emphasized by a joint study by IIT Delhi and Maruti Suzuki. This study also opined that Vehicle-to-Vehicle (V2V) can be one of the potential future enhancements that can be made to enhance the performance of ADAS on the Indian roads [9].

Localization is a very important step to make ADAS operate in India. The recent studies have been aimed at developing solutions based on the local conditions. An example of this is a study on the roads in Hyderabad which resulted in the prototype of autonomous electric vehicle (AEV) that will be able to detect potholes on the road in real-time. The models of deep learning that were utilized in this study include [10].

The 8-bit YOLOv9 to reach a high Mean Average Precision (MAP) of 0.92 in detecting potholes. An additional model applied to identify the semantic segmentation of the study was DeepLabv3+, which was used to identify the "drivable area" for the roads that have no clear markings that would be considered lanes (Mohammed, 2018). The other study suggested a solution of real-time pothole detection based on the. The YOLOv5 algorithm with a MAP of 84.5% and regarded as simple and more accurate than older algorithms [11].

Besides technical barriers, the literature also indicates that there are major non-technical barriers to the adoption of ADAS in India. The gap in research that is significant is the absence of a proper regulatory framework since there are no guidelines on the mandatory features and testing even after introducing the Bharat NCAP safety ratings. The exorbitant price of ADAS is also an obstacle, and these systems cannot be afforded by a large number of consumers. The fact that there is an overall lack of consumer awareness and proper driver training contributes to the underutilization of this issue and the perception that ADAS is a luxury, and not a necessity [12].

According to some authors, simple algorithms and low-cost, high quality cameras and sensors can be used successfully to construct ADAS. Although today ADAS is available primarily in high-priced vehicles, one article notes that the technology might be an essential aid in collaborating to minimize accidents in India where more than 135,000 people are killed each year on the roads. In another study, an ADAS was suggested based on computer vision and the Internet of Things (IoT) to allow V2V and V2I (Vehicle-to-Infrastructure) communication. The system observes the parameters of vehicles in order to make personalized driving recommendations. One of the main peculiarities is that it can be updated via over the air (OTA), so it is possible to upgrade

software remotely to enhance the experience of driving a vehicle. A survey by HERE Technologies main brain of the system will be Raspberry Pi. It will conducted recently revealed that, although 98% of Indian road users care about road safety, only 49% think that their roads are safe. The survey also found out that the leading causes of accidents are the reckless driving and poor road conditions. A massive 91% of the people interviewed feel that ADAS plays a vital role in safety, 82% would purchase a car with ADAS which indicates high demand yet low uptake [14], [15]

III. METHODOLOGY

A. Architectural design of ADAS prototype:

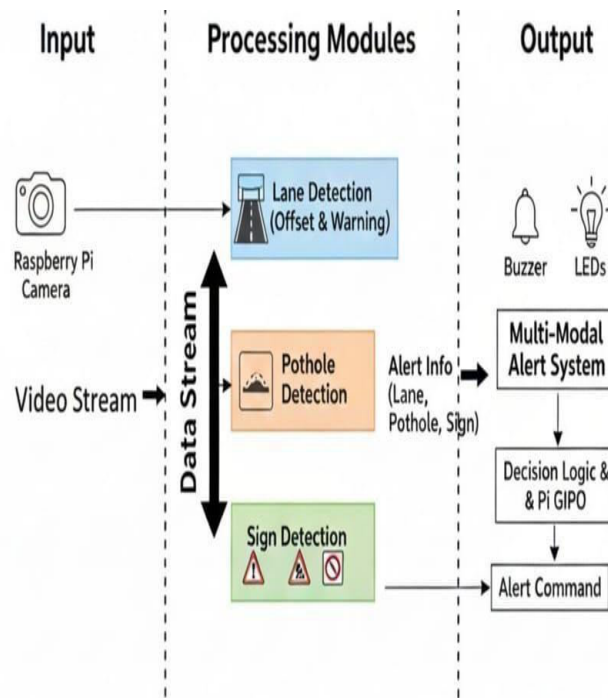


Fig 1: System Architecture

Having a highly developed system architecture is what makes an ADAS effective in terms of its capabilities to process complex sensor data and provide a response in real-time. The section presents the proposed architecture design, which includes data flow and the interaction of hardware and software parts.

A. System Architecture

Proposed System Architecture :A Centralized Compute System

Our proposed ADAS is designed to work on the Indian roads where the lanes and traffic is quite unorganized. It incorporates low-cost hardware that has smart computer vision and deep learning to deliver real-time support. The system comprises three key components, including data collection, data processing, and driver alert system. Our proposed ADAS is designed to work on the Indian roads where the lanes and traffic is quite unorganized. It incorporates low-cost hardware that has smart computer vision and deep learning to deliver real-time support. The system comprises three key components, including data collection, data processing, and driver alert system. It will execute the software, read video through a camera, deep learning models, and turn on output hardware such as a buzzer or a light. Its size is small and consumes less power hence fitting this project. The system begins with the live video feed of one camera of high quality in the front of the car. The primary input of all this is this video. The video information is transmitted to the central computer which is then transmitted to four software modules that are simultaneously running: a lanes module, a potholes module, a signs module, and a driver drowsiness module . All the data of these modules is then put together so as to have a complete picture of the surrounding, which is then used to know when to warn the driver.

B. Hardware And Software Co-Design

It is not only the code that makes the system fast enough but also the hardware and software. The hardware should be a fast one to be able to perform numerous tasks simultaneously. The application will be developed based on a real-time operating system (RTOS) to be fast. Major tools such as OpenCV are used in simple image processing. It would be too

slow and unreliable to run the four modules sequentially. This is why we have selected a centralized this architecture. This design enables the simultaneous operation of tasks, which is the most significant element of the feasibility of a real-time ADAS prototype.

The basic aspect of the hybrid methodologies is. OpenCV, a vital library to some of the most common image processing methods, including: grayscale conversion, thresholding, and contour detection. Designing a working, multi-functional ADAS prototype involves more than the selection of the appropriate algorithms; it involves the development of a system that integrates them together to be capable of running them in parallel with a high frame rate. A purely sequential performance of the four computationally intensive modules would present a considerable amount of latency, rendering the system unsafe when used in the real world

This architecture is very important to this as it offers a single platform through which one can run multiple tasks simultaneously with particular cores executing specific workloads. This is the most important architectural decision that should be made in making sure that a real-time ADAS prototype is viable.

C. Vision Based Perception Module

The system has a single camera on its front side which serves as the primary sensor. This has been central in its capability to respond immediately and multitask. The prototype consists of four primary sections to address the unique tasks of Indian roads namely lane and drive area identification, pothole identification, traffic signs identification, and drowsiness of the driver. It combines classic computer vision with an advanced deep learning to achieve the most effective results.

- **Lane and Drivable Area Detection**

A mixed approach will be to address faded lanes in India. Lane lines and the safe driving on the road area will be identified by AYOLOv5 segmentation model. We will then apply OpenCV to make the images sharper before that, as it aids in locating subtle markings. The model will also be trained to detect the road driving area.

- **Pothole Detection and Road Assessment**

Traditional methods of finding characters with OpenCV a whole lot simpler, you color isolating for dark areas and then search for them but they can easily be fooled by shadows. For more consistent results, our system will employ a two-phase approach. OpenCV finds potential potholes, and a deep-learning model (for example, an optimized YOLOv5) confirms whether it is an actual pothole or not. The key here how you filter out shadows and other false positives while keeping it fast.

- **Indian Traffic Sign Recognition**

It is specifically designed for Indian road signs. A new deep learning model called Refined Mask R-CNN will be used for this purpose. The first will be to detect his sign on OpenCV and then utilize module OCR (Optical Character Recognition) to read texts in it. It will be custom trained on Indian road signs database.

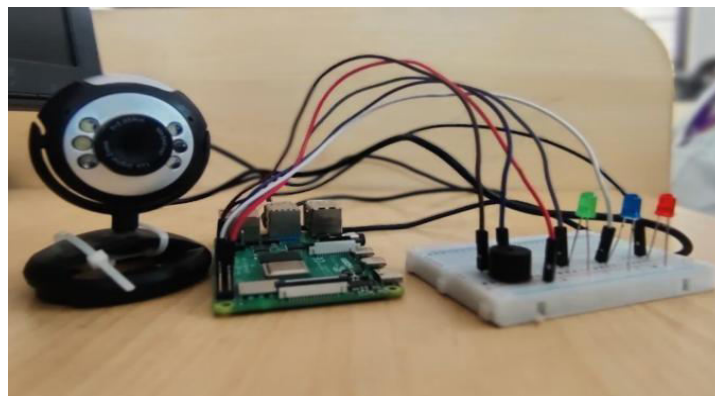


Fig 2: Model Structure

Table 1: Vision-based ADAS Modules: Methodologies & Key Tools

Module	Primary Methodology
Lane Detection	Hybrid deep learning and computer vision for segmentation
Pothole Detection	Hybrid candidate extraction and deep learning classification
Traffic Sign	Deep learning with pre-processing and OCR

A. Tools And Technologies

This book details the development of a proof-of-concept implementation of an Advanced Driver Assistance System (ADAS) for Indian roads with chaotic traffic conditions, non-existent/poorly marked lanes and diverse factors including weather conditions, traffic signs, obstacles and accidents.

A full vision-based system design consisting of a centralized computing unit for real-time object/scene detection is presented, covering algorithms related to Lane, Drivable Area Detection, Pothole/Road Surface Analysis, Indian Traffic

B. Sign Recognition and Driver Drowsiness Alert System.

The book does not rely on a single algorithmic solution; instead, a hybrid structure leveraging traditional computer vision methods and contemporary deep learning models for each task to ensure robustness and fault tolerance is described. The use of libraries such as OpenCV and YOLOv5 is covered. The book also covers the usage of single-board computers such as Raspberry Pi 4 for building the full system on low-latency, low-power devices to maintain real-time processing as required by ADAS applications. This book serves as a technical documentation guide detailing design, implementation, optimization techniques and development to transform an idea into a workable, strong, scalable and extendible solution.

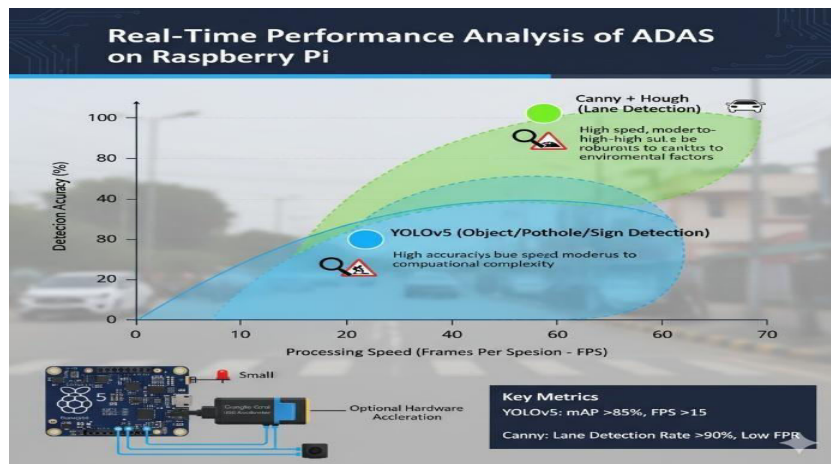


Fig 3: Analysis on Raspberry Pi

IV. RESULT AND EVALUATION

The goal of this project is to develop a prototype of an Advanced Driver Assistance System (ADAS) suitable for mixed-traffic roads in India. The chosen prototype and the hybrid approach taken to develop it help compensate for various weaknesses of each approach. Being flexible is important for a system to be applied on roads with a high variety of traffic conditions such as Indian roads. A hybrid approach combining traditional computer vision and deep learning helps to compensate for the individual weaknesses of both paradigms. Computer vision techniques such as OpenCV and YOLOv5 are used for detecting very faint lane lines. A two-step pothole detection approach is proposed

to reduce the number of false alarms triggered by shadows. A centralized computer design is chosen for our Level 3 system.

A Raspberry Pi is used as the central computer, ensuring that all tasks are processed in time and safety-critical delays are avoided. Custom datasets for ADAS are emphasized as being important for the success of ADAS. Standard datasets from other countries aren't useful for India's unique traffic, which includes animals and jaywalking pedestrians. Making a high-quality local dataset is a crucial first step that will help the entire Indian ADAS research community



Fig 4: Lane tracking.



Fig 5: Pothole Detection



Fig 6: Sign Detection.

V. FUTURE DIRECTION

This prototype can be improved in several ways. The system's flexible design allows for a gradual upgrade from a camera-only system to a more advanced one.

Adding More Sensors: The current camera-based system could be improved by adding data from other sensors. Combining camera data with information from radar and LiDAR would help the system see better in bad weather like rain and fog.

V2X Communication: A big step for the future is adding V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communication. This would let the car share and receive real-time information about traffic and road conditions from other cars and city infrastructure.

OTA Updates: Using a cloud connection, the system's software could be updated remotely through OTA (Over-the-Air) updates. This would allow new features and fixes to be sent to the car without a service visit.

VI. CONCLUSION

The ADAS IoT device is built on a single board computer Raspberry Pi, running a software stack comprising ADAS. The IoT device monitors Indian Roads using a camera and notifies the driver using a buzzer and/or LED in real time. The ADAS IoT device uses OpenCV and YOLOv5 and Canny Edge Detection, which perform functions such as Canny Edge Detection for pothole detection, lane following and sign recognition. The device provides a technological solution to the current challenges faced by India in building safe vehicles. It is able to use the resources of the Raspberry Pi to perform ADAS functions using computer vision.

This is further augmented by the AI model to improve performance on resource-limited platforms. The ADAS IoT device aims to provide an efficient, safety system that can operate on a single Raspberry Pi with low latency and low power consumption. By effectively utilising the power of computer vision and AI, the device aims to provide an easy to deploy, real time, safety system for driver assists. The ultimate goal is to create a low cost, easy to operate safety system that provides an electric impulse to the vehicle in real time as a safety system. Level 3 ADAS for Indian Roads is a important challenge due to a wide range of technical, infrastructure and policy problems. No solution has yet been deployed at scale due to various problems.

India has access to global technology but no solution has yet been deployed at scale due to technical, infrastructure and policy problems in matching global technology to India's unique roads. We believe that by taking a local data-driven approach, we can build IoT devices that solve the problems of India. Our first focus will be on deploying an ADAS prototype IoT device that uses computer vision and AI models to perceive India's roads using a local dataset. This will be further augmented with various other functions to make the IoT device more efficient. Future enhancements of the device will include enhancing the researchers' AI models using V2V and/or V2I (vehicle-to-vehicle and/or vehicle-to-infrastructure) communication.

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