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***College of Engineering and Technology***

***Department of Mechatronics Engineering***

B. Eng. Final Year Project

**Advanced Driver Assistance Systems (ADAS)**

By:

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# Introduction

Advanced Driver Assistance Systems (ADAS) represent a key technological advancement in the automotive industry, offering enhanced safety, comfort, and efficiency in driving. ADAS encompasses several technologies, including Forward Collision Warning (FCW), lane-keeping assist and blind-spot detectio aimed at reducing human error. The growing prevalence of these systems around the world is part of a broader movement toward fully autonomous vehicles. This review explores ADAS-related methods and technologies, comparing them with similar projects both globally and locally to evaluate their effectiveness, relevance, and impact on road safety.

# Literature Review

Advanced Driver Assistance Systems (ADAS) represent a major leap forward in automotive safety, leveraging a range of technologies such as sensors, cameras, radar, and artificial intelligence to assist drivers in making safer decisions. These systems can detect road conditions, monitor vehicle surroundings, and in some cases, take corrective actions to prevent accidents. This review explores various ADAS projects around the world, comparing their methodologies and technologies with a particular focus on the ADAS project being developed for the graduation project. The evaluation will assess how this project stands in relation to global and local advancements.

# Our ADAS graduation project integrates several core components:

Our project incorporates **Lane Departure Warning, Interactive Surface, Blind Spot Detection,**and**Forward Collision Warning** using an Ackerman chassis for steering. Let's compare our methods and technologies to similar ADAS initiatives globally and locally.

* **Technology**

Our ADAS utilizes radar sensors, cameras, and machine learning algorithms for feature detection and vehicle control, aligning with systems like Tesla’s Autopilot and Waymo’s platform in terms of sensor diversity. Unlike LiDAR-dependent systems such as Waymo's, our system prioritizes radar and camera integration, making it more cost-effective and suitable for markets where LiDAR may be financially impractical.

* **Cost Efficiency**

A core strength of our project is its focus on affordability without sacrificing safety. Global projects by Tesla and BMW offer advanced features, but their high costs limit accessibility, especially in developing regions. Our project uses cost-effective sensors and open-source software to deliver comparable safety features at a fraction of the cost, making it more viable for local markets and budget-conscious consumers.

* **Integration and Customization**

Our project emphasizes a modular ADAS design, integrating systems like Blind Spot Detection,  and Forward Collision Warning into one cohesive unit. This gives us a significant edge over many local ADAS projects, which often focus on just one or two features. In terms of scope, our project aligns more closely with commercial systems from Volvo and Tesla, bundling multiple safety and assistance features together.

* **Community Impact**

While global systems mainly target high-end vehicle markets, our project is designed to significantly impact local driving conditions, where many vehicles lack advanced safety features. By focusing on essential ADAS functions such as Blind Spot Detection and Adaptive Cruise Control, we address key local driving challenges, such as frequent accidents due to blind spots and unsafe following distances on highways. This approach surpasses local university projects, which often emphasize basic functionality without considering market-ready deployment.

# Strengths and Weaknesses of the ADAS Graduation Project

Strengths:

1. The project focuses on affordability by using Ultra Sonic and camera-based systems instead of expensive LiDAR. This makes the system more accessible to developing markets and budget-conscious consumers.
2. It integrates multiple ADAS features, such as blind spot detection, adaptive cruise control, and lane departure warning into a single cohesive system, offering a comprehensive solution comparable to high-end commercial systems.
3. By focusing on essential ADAS functionalities, the project addresses specific local driving challenges, such as blind spot accidents and unsafe highway driving practices, making it highly relevant for improving road safety.
4. Incorporating machine learning algorithms for feature detection enhances the system’s ability to adapt to different driving environments, improving accuracy and decision-making.

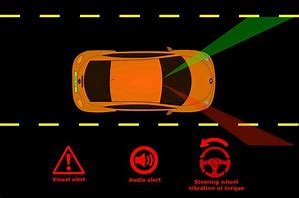
## Weaknesses:

1. The integration of multiple ADAS features into one system could pose challenges in terms of coordination, reliability, and real-time data processing, especially on lower-cost hardware.
2. While the customization for local environments is a strength, it could limit the system’s applicability in other regions without significant adjustments, reducing scalability outside its target market.
3. As with any ADAS, there could be challenges with user interaction, where drivers may not fully understand the system's capabilities and limitations, leading to misuse or over-reliance.

## **Literature Review of ADAS Features and Their Applications**

## **Lane Departure Warning and Lane Keeping Assist Systems**

Figure 1 (Lane Departure Warning)[1]

The development of Advanced Driver Assistance Systems (ADAS) has been transformative in improving vehicle safety. A key aspect of ADAS technology is the lane departure warning (LDW) and lane-keeping assist (LKA) systems, which help prevent unintended lane departures, a leading cause of highway accidents. In this section, we will review the historical development of LDW and LKA systems, comparing these advancements globally, and evaluate our ADAS project within this context. [1]

### Expansion Across Vehicle Manufacturers

By 2003, lane departure technology had evolved significantly, with **Honda** introducing its Lane Keep Assist System (LKAS) on the Inspire model. Unlike earlier systems, LKAS could provide steering torque to keep the vehicle within lane boundaries, minimizing the need for constant driver input on highways. A camera mounted at the top of the windshield tracked lane markings, and the system calculated necessary steering adjustments using factors such as yaw and vehicle speed [2].

Around the same time, **Toyota** introduced a lane monitoring system that used visual markers to alert drivers of unintended lane departures, integrating it into various models in Japan[3]. By 2004, **Citroën** became the first European automaker to offer LDWS in its passenger vehicles [4].

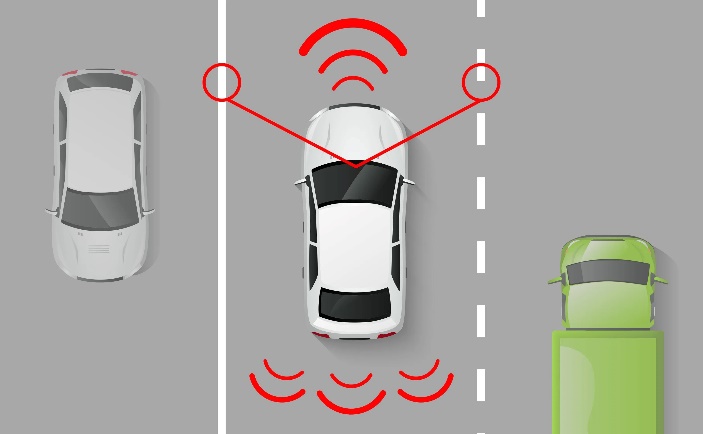


Figure 2 (Toward Lane-Keeping Systems)[3]

### Technological Advancements: Toward Lane-Keeping Systems

In 2006, **Lexus** introduced a more advanced system that combined LDW and LKA features, capable of applying corrective steering torque to prevent overcorrection by the driver[5]. Similarly, **Audi** and **Infiniti** implemented systems that used advanced sensors and cameras, improving lane detection and assistance accuracy [6].

### Further Innovations: Mobileye and Automated Lane Assistance

By 2008, companies like **BMW** and **General Motors** integrated Mobileye’s core technology into their LDW systems, allowing for better image processing and lane detection. Mobileye's algorithms significantly improved the reliability of lane departure systems, while companies like **Volvo** and **Mercedes-Benz** added further refinements, such as Steering Assist

In **2014**, companies like **Tesla** pushed the boundaries of LKA with their **Autopilot** system, which offered both reactive and proactive lane-keeping capabilities. By utilizing neural networks and deep learning, Tesla’s system could adapt to various road conditions and driving behaviors, laying the foundation for future autonomous vehicles. [7]

### Evaluation of Our ADAS Project

in comparison to the existing literature and technology, our ADAS project seeks to enhance lane departure and lane-keeping systems by focusing on deeper integration with other ADAS features, such as Forward Collision Warning Utilizing image processing techniques like the **Hough transform** and **Canny edge detection**, our system will provide real-time lane detection with higher accuracy.

Moreover, unlike earlier systems that relied on simple alerts, our approach integrates **haptic feedback**, **visual indicators**, and **adaptive steering adjustments**, ensuring a safer and more intuitive driver experience. These methods will provide drivers with clear and immediate warnings when lane departure is imminent while also offering automatic corrections to help maintain the vehicle’s position within the lane.

In summary, our ADAS project builds on the foundational work of companies like Iteris, Honda, and Tesla while pushing the boundaries of lane detection and correction technologies. The ultimate goal is to deliver a comprehensive, next-generation lane assistance system that not only prevents lane departure accidents but actively enhances driver confidence and comfort. [8]

# C:\Users\Home\Downloads\WhatsApp Image 2024-10-19 at 9.28.23 PM.jpegBlind Spot Detection (BSD) systems

Figure 3 (Blind Spot Detection)[7]

This literature review explores Blind Spot Detection (BSD) systems in Advanced Driver Assistance Systems (ADAS), highlighting methodologies and sensor technologies used by various automotive manufacturers, evaluating their effectiveness, and positioning the proposed project against existing global and local implementations.

### Review of Existing BSD Systems in ADAS

1. **BMW’s** Active Blind Spot Detection employs radar sensors in the rear bumper to monitor adjacent lanes. It provides visual warnings in the side mirror and triggers tactile feedback if a lane change is attempted with a vehicle in the blind spot. This system is effective in alerting drivers but primarily reactive, catering to those who respond well to warnings.

2. **Mercedes-Benz** utilizes radar-based Blind Spot Assist, featuring short-range sensors that display visual alerts in the side mirror. The Active Blind Spot Assist can actively apply braking on one side if the driver attempts to change lanes into an occupied space. This proactive approach enhances safety, but its complexity may increase costs.

**Early Innovations**

* **Radar-Based Systems**: The first significant innovation came with the introduction of radar technology in the late 1990s. Radar sensors placed in the rear corners of vehicles could detect objects in adjacent lanes.
* **Ultrasonic Sensors**: These sensors were developed to provide proximity detection, working effectively at low speeds and in parking scenarios.
* **Camera Systems**: The integration of cameras for visual detection became a prominent innovation, providing a visual feed to drivers and aiding in situational awareness.

**Prototyping**

* **Development of Prototypes**: Engineers created early prototypes combining radar, ultrasonic sensors, and cameras. Testing involved controlled environments to assess their effectiveness in detecting vehicles in blind spots.
* **User Feedback**: Early user feedback was integral in refining the technology. Drivers reported on the reliability and responsiveness of alerts, leading to enhancements in sensor placement and algorithms. [10,12]

**Modern Developments**

* **Enhanced Algorithms**: Advances in machine learning have improved the accuracy of BSD systems, allowing for better identification of vehicles, cyclists, and pedestrians.
* **Integration with Other Systems**: Modern BSD systems are now often part of a suite of safety technologies, including cross-traffic alerts and 360-degree cameras.
* **User Interfaces**: Innovative alert systems, such as visual indicators in side mirrors and auditory signals, enhance driver awareness without causing distraction.

### - Technology Comparison:

* + The proposed system combines radar ,Ultra Sonic sensors, akin to existing systems like BMW and Toyota, with camera detection to improve accuracy in complex environments. This dual-sensor approach parallels Tesla’s methodology but aims to achieve similar benefits at a lower cost.
  + The combined radar, Ultra Sonic and camera sensors enhance detection accuracy, especially in adverse weather or lighting conditions, making it suitable for various driving environments.
  + However, the dual-sensor system may increase costs compared to simpler radar-only systems, potentially limiting adoption in budget-sensitive markets. [10,12]

### - Methodology Comparison:

* The proposed system features visual alerts through side mirror indicators, audible warnings, and optional steering feedback to assist the driver in lane maintenance. This aims to balance passive alerts with active support, similar to Mercedes-Benz’s systems.
* Offering both proactive feedback and intuitive visual alerts, the proposed system accommodates a wide range of drivers, enhancing safety.
* Compared to systems providing automatic braking (e.g., Mercedes-Benz), reliance on steering feedback may be less effective in emergencies requiring braking. [10,12]

## Global and Community Impact of BSD in ADAS

1. **Global Context**

- The global ADAS market, especially in luxury vehicles, is increasingly integrating BSD. However, high costs limit accessibility.

- This project aims to offer similar safety at a lower cost, making advanced ADAS features more accessible to mid-range vehicles, improving road safety in cost-sensitive regions.

2. **Community Context**

- Many drivers with older vehicles lack modern ADAS due to high upgrade costs.

- This project provides a retrofittable solution, enhancing safety without requiring new vehicle purchases, particularly for markets with older vehicle demographics.

- Its adaptability allows customization for local driving conditions, offering a tailored alternative to standardized global systems. [14]

### Evaluation of Blind Spot Detection in the ADAS Project

The Blind Spot Detection (BSD) system in our Advanced Driver Assistance Systems (ADAS) project is designed to enhance vehicle safety by providing real-time monitoring of adjacent lanes. This evaluation assesses the system's effectiveness, methodology, technological integration, and potential impacts on drivers and road safety.

**Effectiveness:**

The BSD system uses ultrasonic and camera sensors to detect vehicles in blind spots, offering improved accuracy over radar-only systems. The visual data enhances detection, especially in heavy traffic or bad weather. Real-time alerts, both visual (side mirror indicators) and audible, warn drivers of vehicles in the blind spot or during lane change signals, reducing collision risks.

**Methodology:**

The BSD system incorporates both passive and active safety features. Visual alerts in the side mirrors provide immediate feedback to drivers, while audible warnings serve to capture attention in critical moments. The optional steering feedback feature encourages the driver to maintain lane discipline, enhancing overall situational awareness. This proactive approach is designed to assist drivers who may not be accustomed to advanced safety features, making it accessible to a wider range of users, from novice to experienced drivers.[19]

**Technological Integration**

The integration of Ultra Sonic and camera technologies presents several advantages:

* **Enhanced Detection:** The combination allows for improved detection performance in various environmental conditions, such as low visibility due to rain or night driving.
* **Cost-Effectiveness:** While dual-sensor systems can be more expensive, the proposed design aims to balance affordability with high functionality, making advanced safety features more accessible to mid-range vehicles.
* **Adaptability:** The system can be customized to suit different vehicle models and local driving conditions, addressing the unique challenges faced by drivers in various environments.

**Challenges and Considerations**

Despite its advantages, the BSD system does face challenges:

* A screenshot of a device

  Description automatically generated**Driver Dependence:** There is a risk that drivers may become overly reliant on the system, potentially diminishing their attention to surrounding traffic conditions.

Figure 4 (Ackerman Chassis)[17]

* **Cost Implications:** While the proposed design seeks to balance cost and effectiveness, implementing advanced sensor technologies may still be a barrier for budget-sensitive markets.
* A black metal frame with wheels

  Description automatically generated**Regulatory Compliance:** Ensuring the system meets local safety regulations and standards is crucial for successful implementation. [11,14]

Figure (Ackerman Chassis)[17]

Figure 6 (Ackerman Chassis)[17]

# Ackerman Chassis Methods

## Literature Review

The Ackerman chassis design is fundamental for improving vehicle cornering by ensuring that each wheel follows a unique turning radius, preventing tire scrubbing during turns. This principle is particularly vital in high-performance automotive and robotics applications, where precise steering response and handling are crucial. [16,17]

## Key Methods in Ackerman Chassis Design

Ackerman steering geometry is widely implemented in both commercial and research vehicles to align the inside and outside wheels during cornering, optimizing traction and minimizing tire wear. Key design factors include caster angle, kingpin inclination, and slip angle, all of which affect handling performance. Variables like weight distribution and mass transfer during dynamic conditions are also considered.

Recent research explores dynamic Ackerman models that adjust geometry based on real-time speed or cornering forces, enhancing vehicle stability at high speeds. For example, race cars often employ non-linear Ackerman setups to provide flexibility in varying cornering conditions and minimize oversteer or understeer.

[17] [18] .

**Comparison with Global and Local Projects**

1. **Global Applications**: Research in electric and autonomous vehicles highlights Ackerman steering as critical for path tracking and obstacle avoidance. Projects like Tesla's **Autopilot** incorporate adaptive steering models that simulate Ackerman principles with slight modifications to address varying road conditions and sensor inputs. Similarly, experimental autonomous shuttles in Europe integrate Ackerman geometry for precise, low-speed maneuvering through urban environments.[16,17]
2. **Local Projects**: In regions like Egypt and other emerging markets, research efforts in Ackerman chassis focus on affordable manufacturing and robustness for uneven roads. Projects in these communities emphasize mechanical simplicity to reduce costs while retaining the essential benefits of Ackerman geometry. Such solutions are particularly useful for utility vehicles and smaller electric cars designed for congested urban areas. [17]

**Evaluation of Ackerman Chassis**

Ackerman steering enhances cornering, but its limitations at high speeds due to tire deformation and load shifts prompt the exploration of alternatives like parallel steering and dynamic rear-wheel steering, especially in motorsports and luxury cars. Hybrid approaches, combining partial Ackerman geometry with other systems, can offer tailored solutions for specific terrains or vehicle needs, such as desert travel or tight urban navigation. Further research into adaptive and hybrid steering models can broaden the application of these benefits.[16,17]

Many well-known performance and racing cars use **Ackermann steering geometry** to improve cornering precision and reduce tire wear. Here are some examples:

**1. Formula 1 Cars**

* **F1 cars** benefit from optimized Ackermann geometry to improve tire contact during sharp turns. The tight setups used help reduce scrub (unwanted tire sliding) at low speeds, giving drivers precise control in corners​.[17]

Many modern vehicles, especially those prioritizing smooth turning and stability at low speeds, use Ackermann steering geometry. Globally, it's incorporated into a variety of road cars, racing vehicles, and autonomous cars. Some prominent brands and models that utilize or modify this steering concept include:

1. **Passenger Cars**: BMW and Mercedes-Benz have vehicles that apply Ackermann geometry principles for improved cornering performance and tire wear. Models like the **BMW 3-Series** and **Mercedes E-Class** benefit from these designs, ensuring better handling in urban driving and smoother cornering.[17]
2. **Motorsport Cars**: Some high-performance race cars, including drift and rally vehicles, tweak the Ackermann setup for sharper cornering. For instance, drift setups may use adjusted Ackermann angles to enhance tire grip and minimize understeer during tight, controlled slides. [16,17]

# Forward Collision Warning (FCW)

Forward Collision Warning (FCW) systems are critical components of Advanced Driving Assistance Systems (ADAS) aimed at enhancing road safety and reducing traffic accidents. FCW systems utilize various sensors and algorithms to monitor the vehicle’s surroundings, detect potential collisions, and provide alerts to drivers. This literature review examines the methodologies of existing FCW projects globally and within local communities, comparing their strengths and weaknesses. It also discusses the applications of FCW systems in everyday life.

**Methodologies in FCW Projects**

1. **Sensor Fusion Approaches**
   * Many FCW systems employ a combination of sensors, including cameras, radar, and LIDAR, to enhance detection accuracy. For example, the Mobileye system integrates camera data with advanced algorithms to identify vehicles and pedestrians, providing timely warnings.
   * **Strengths:** Increased reliability and robustness in various environmental conditions.
   * **Weaknesses:** Higher costs and complexity in system integration.
2. **Machine Learning Algorithms**
   * Some projects leverage machine learning techniques to improve object recognition and collision prediction. The Tesla Autopilot, for instance, uses neural networks to process real-time data from its camera system.
   * **Strengths:** Enhanced adaptability and improved decision-making capabilities over time.
   * **Weaknesses:** Dependency on large datasets for training, which can lead to biases and require constant updates.
3. **Pre-Crash Brake Assist (Optional)**:

* In some vehicles, FCW is complemented by Pre-Crash Brake Assist (PCBA) or Automatic Emergency Braking (AEB). If the driver doesn’t respond to the warning alert quickly enough, these systems can automatically apply the brakes to reduce the impact of the collision or even prevent it entirely. [13]

**Global and Local Comparisons**

Globally, advanced FCW implementations can be found in systems like the Ford Co-Pilot360 and BMW Active Driving Assistant, which offer a range of features, including Forward Collision Warning and lane-keeping assistance. In contrast, local community implementations may be limited to basic warning systems integrated into older vehicles, often relying solely on radar or camera sensors.

* **Strengths of Global Systems:**
  + Comprehensive integration with other ADAS features.
  + Greater funding and technological resources leading to continuous improvement.
* **Weaknesses of Local Systems:**
  + Limited functionality and reliance on outdated technology.
  + Lack of awareness and training among drivers, leading to underutilization.

**Applications of FCW in Everyday Life**

FCW systems have various applications, enhancing safety in numerous driving scenarios:

* **Passenger Vehicles:** Most modern cars feature FCW systems to alert drivers of potential frontal collisions, contributing to safer driving experiences.
* **Commercial Vehicles:** FCW is increasingly integrated into trucks and buses, where the risk of severe collisions is higher due to their size and weight. [9]

**Reaction time**

While our brains are evaluating these inputs we continue to travel towards the hazard. The amount of time you take from first seeing the hazard to taking action is the reaction time. Typically this is between 1-2 seconds depending on your age and experience. Younger people might have faster general reactions but not the experience to make the decision quickly enough, while older people have slower reactions but more experience. [11]

**System Architecture and Implementation**

The FCW system in our ADAS project is designed to utilize a combination of sensors primarily radar and depyth camera or lidar to detect potential collisions with vehicles, pedestrians, and obstacles ahead. The architecture consists of:

1. **Sensors:**
   * **Sensors:** Used for long-range detection of vehicles and obstacles, providing accurate speed and distance measurements.
   * **Camera:** Offer visual data for object recognition and classification.
2. **Processing Unit:**
   * A dedicated processing unit analyzes data from the sensors using algorithms that assess the risk of collision.
3. **Alert Mechanism:**
   * The system triggers visual and auditory alerts to notify the driver when a potential collision is detected. [14]

**Strengths of the FCW System**

1. **Increased Safety:**
   * The FCW system significantly enhances driver awareness, allowing for timely intervention in potential collision scenarios. This proactive approach is essential in preventing accidents.
2. **Real-time Monitoring:**
   * The combination of radar and camera data enables continuous monitoring of the vehicle's surroundings, ensuring a reliable detection of threats.
3. **User-Friendly Alerts:**
   * The alert mechanisms are designed to be intuitive, minimizing distractions while providing clear warnings to the driver. [9]

**Weaknesses of the FCW System**

1. **Environmental Limitations:**
   * The system's performance can be affected by adverse weather conditions (e.g., heavy rain, fog, snow) that may impair sensor functionality.
2. **False Positives:**
   * There is a risk of false alarms due to misinterpretation of sensor data, which can lead to driver frustration and reduced trust in the system.
3. **Dependence on Driver Attention:**
   * The FCW system relies on the driver’s engagement and response to alerts. If the driver is distracted or unresponsive, the system's effectiveness diminishes.
4. **Cost Considerations:**
   * Implementing advanced sensor technologies may increase the overall cost of the vehicle, which could be a barrier to widespread adoption. [14,15]

**Applications of FCW in Daily Life**

The application of the FCW system extends beyond individual vehicles to broader contexts:

* Honda Forward Collision Warning (FCW)
* Mazda Forward Obstruction Warning (FOW)
* **Urban Driving:** In busy city environments, FCW aids in navigating dense traffic and avoiding potential collisions with pedestrians and cyclists.
* **Highway Driving:** The system supports safe merging and lane changes, crucial for long-distance travel.
* **Commercial Use:** In logistics and public transportation, FCW enhances safety for drivers and passengers, contributing to overall operational efficiency. [15]

**Conclusion**

The ADAS project, integrating key features such as Blind Spot Detection (BSD), Forward Collision Warning (FCW), and Lane Departure Warning (LDW), demonstrates a significant step toward developing cost-efficient safety solutions within the automotive industry. By employing more affordable sensors and open-source software, this initiative aims to democratize access to advanced driver assistance technologies, particularly in markets where the adoption of high-end systems is constrained by financial barriers.

This project not only addresses global challenges by enhancing accessibility to ADAS technologies but also delivers substantial local impact. Its retrofittable solutions for older vehicles provide a practical approach to improving road safety without necessitating costly vehicle replacements. This is particularly advantageous in regions with aging vehicle populations, where new car purchases may not be financially feasible.

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