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Advanced Driver Assistance System

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***Abstract*—Advanced Driver Assistance System(ADAS) has become a salient feature for safety in modern vehicles. They are also a key underlying technology in emerging autonomous vehicles. State-of-the-art ADASs are primarily vision based,but light detection and ranging(lidar),radio detection and ranging(radar) and other advanced-sensing technologies are also becoming popular. In this article, we present a survey of different hardware and software ADAS technologies and their capabilities and limitations. We discuss approaches used for vision based recognition and sensor fusion in ADAS solutions. We also highlight challenges for the next generation of ADAS.**

***Keywords*—Advanced Driver Assistance System, ADAS, vehicle safety, technology, challenges, future trends.**

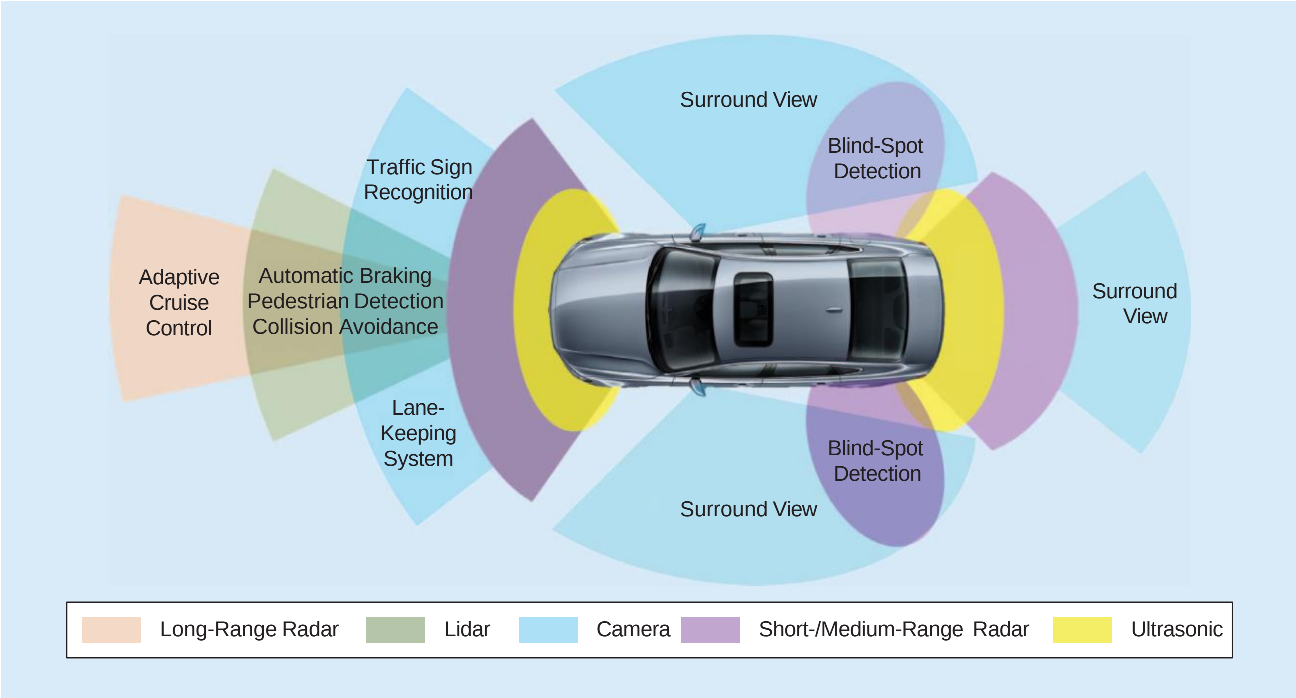
INTRODUCTION

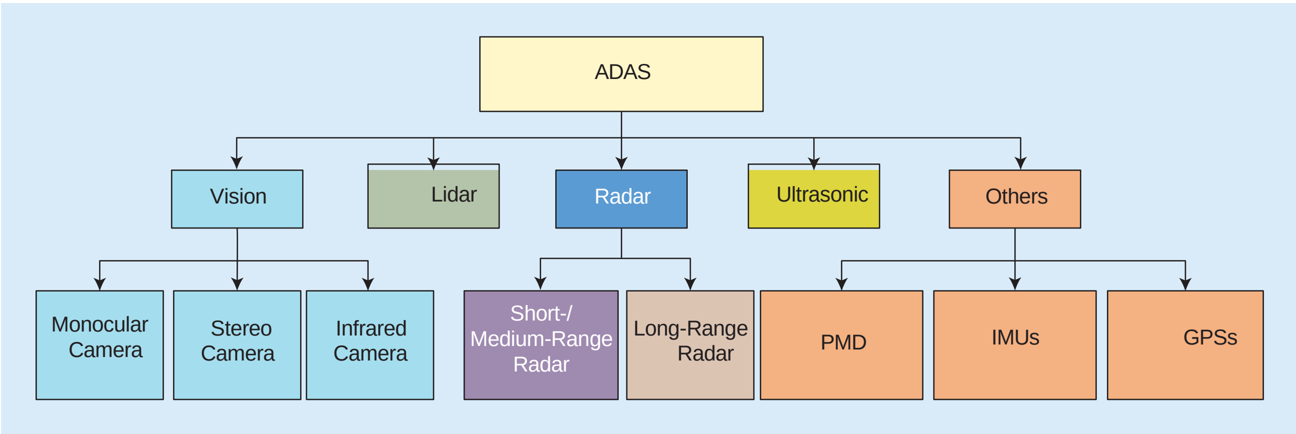
This paper presents a comprehensive review and analysis of Advanced Driver Assistance Systems(ADAS) focusing on their technology , benefits, challenges, and future trends. ADAS have significantly advanced vehicle safety, comfort, efficiency.The review includes an overview of various ADAS technologies such as adaptive cruise control, lane departure warning, and automatic emergency braking. The paper also discusses te integration of these systems into vehicles, their impact on reducing accidents, and the challenges of implementation. Finally, future directions for ADAS development and research are outlined.These systems utilize various sensors, cameras, and computational algorithms to assist drivers in different aspects of driving. The goal of this paper is to provide an in-depth analysis of ADAS, including their technology, benefits , challenges and future trends.

Overview of Automotive Safety System

Safety in automotive systems has been a major concern since the early days of on-road vehicles.These systems are mainly classified into two types: 1)Pasive(or reactive) and 2)Active(or proactive). Passive safety safety systems protect vehicle occupants from injuries after a crash, eg. Seat belts, air bags, and padded dashboards.Active systems are one of the main areas of interest and have seen major growth in today's vehicles. eg. Lane keeping, automatic braking and daptive cruise control. These systems are commonly known as ADASs and are becoming increasingly popular as a way for automotive manufacturers to differentiate their offerings while prooting consumer safety.

Recent studies from World Health Organization indicate that 1.25 million deaths occur every year due to road traffic accidents.Moreover, with increasing number of electronic control units and integration of various types of sensors, there are now sufficient computing capabilities in vehicles to support ADAS deployments.The different types of sensors,such as cameras, lidar, radar, and ultrasonic sensors enable a variety of different ADAS solutions. Among them, the vision based ADAS, which primarily uses cameras as vision sensors is popular in most modern-day vehicles.





Modern day ADASs are also key technologies to realize autonomous vehicles.But several challenges with the design, implementation an operation of ADASs remain to be overcome.This paper provides synopsis of the landscape of ADAS research and development to address challenges

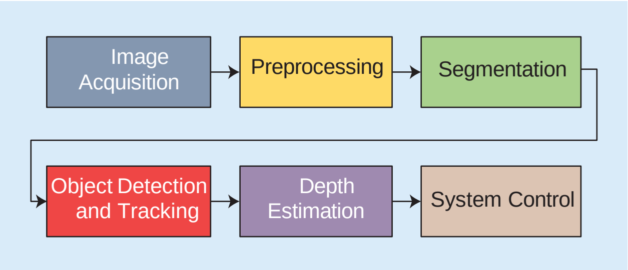
ADAS Taxonomy

***Vision Sensors** : Vision based ADAS relies on cameras to capture images and detect objects. They're commonly used in vehicles due to their low cost and esay installation. Cameras provide rich information like color and texture, giving them an advantage over other sensors. There are two main types : monocular, which uses single lens, and stereo, which uses multiple lenses for depth perception. Monocular cameras are simpler and cheaper, while stereo cameras offer better depth perception. Both types are vital for enhancing vehicle safety and convenience.*

Monocular Cameras: *Monocular camera systems have one lens and lower image-processing requirements. They're used for various applications like obstacle detection,pedestrian recognition, and monitoring the drivers's behavior. However, they lack depth information , making them unreliable for distance estimation. Techniques can approximate distance by tracking key features in captured iamges where the camera is in motion.*

Stereo Cameras *: Stereo camera systems have multiple lenses with image sensors, allowing for 3D information extraction by matching left and right images. They provide accurate depth estimation for various applications like traffic sign recognition and obstacle detection. Stereo cameras are positioned inside vehicles,typically behind rear-view mirror , facing the road, and are effective for distance estimation up to 30 meters.*

IR Cameras *: There are two main types of IR cameras Active IR cameras, these utilize a near-IR light source within the vehicle to illuminate the scene. A standard digital camera sensor captures the reflected light ,which is not visible visible to the human eye. Passive IR cameras, these use an IR sensor where each pixel acts as a temperatue sensor, capturing thermal radiation emitted by materials. Active IR cameras use external illumination, while passive IR cameras rely on detecting thermal radiation.*



LIDAR *: Lidar measures distance by sending laser beams to objects and calculating the time for the light to return. It provides high-resolution 3D images and operates at longer ranges than cameras. Some lidar scanners support surround-view sensors, generating 360 degree 3D images with precise depth inforamtion. Lidar is increasingly popular in autonomous vehicles for tasks like automatic braking and collision avoidance. While effective, lidars are heavy, bulky, and expensive, with their accuracy affected by weather conditions. Solid state lidars offer smaller and cheaper alternatives, promosing enhanced accessibility.*

RADAR : Radar systems use microwaves to detect an object's speed and distance via frequency changes. They work over longer distances and are unaffected by weather. Short, medium, and long-range radars are used for various vehicle applications, from blind spot detection to adaptive cruies control. Ongoing research aims to improve radar performance and reduce costs.

Ultrasonic Sensors : Ultrasonic sensors utilize sound waves to gauge object distance, pimarily for detecting close-range obstacles. They're employed in applications like automatic parking and parallel parking assistance, typically positioned under the vehicle's front and rear bumpers.

Others : Additional sensors like PMD cameras offer fast optical sensing and depth infromation without scanning. IMUs and GPSs improve distance measurements with lidar and radar.

VISION-BASED ADAS

Vision based ADASs rely on images from cameras and use computer vision principles to extract useful information.

Image Acquisition

This process involves capturing a frame from a video, represented as a matrix of pixel data with three channels: red, green, and blue (RGB). Frame rates in ADASs vary from 5 fps to 60 fps depending on the application.Tasks like detecting vehicle proximity require higher frame rates due to rapid distance changes, while traffic sign detection can suffice with lower rates since only one frame is needed for detection.

Preprocessing

Preparing an image for computer vision algorithms involves several common preprocessing steps, including denoising, color enhancement, color space conversion, and image stabilization. For example, converting from RGB to hue, saturation, and value separates color from intensity, with the hue channel often used to isolate adverse effects like shadows and uneven lighting. This aids in easier tracking and detection.

Segmentation

This process involves separating features from a frame by partitioning it into recognizable objects, such as identifying the road and sky as distinct features. Various thresholding techniques are used to filter pixels of one class(eg. road) from another(eg. sky). For example, color information may be exploited to detect a stop sign by looking for red pixels in the image. This results in a binary image where red pixels are turned white and others black, creating a mask for finding the area of interest.

IMUs and GPSs are examples of systems that help improve the distance measurements with lidar and radar.

Object Detection and Tracking

This process involves classifying objects in an image(eg. determining if an object is a vehicle, sign, or pedestrian) and predicting their movement, often using machine learning(ML) algorithms. ML algorithms are trained with large datasets to differentiate between objects. Techniques like cascade classifiers and convolutional neural networks(CNNs) are commonly used. CNNs consist of layers for feature extraction and classification. Frameworks like Caffe, Darknet, and MATLAB are utilized for vision applications. Kalman-filter-based object tracking is also employed to track object velocity.

Depth Estimation

This step involves estimating the distance of an object in the image relative to the camera. Two common methods for depth estimation are : 1)using a stereo camera to create a stereo pair and develop a depth map and 3D point cloud, enabling real-world scene reconstruction and 2)using a monocular camera with techniques like optical flow, calibration, and least squares methods for depth estimation.

System Control

This final step in the vision data flow involves interpreting outputs from previous layers and assigning confidence values to make decisions. It requires weighing each layer in the pipeline. A key challenge is avoiding false detections with high confidence that might override other information. Training with correct data, including various orientations of the object, is essential for achieving high accuracy.

OUTDOOR MONITORING

Pedestrian Detection :

Pedestrian detection involves using multiple classifiers due to pedestrian's varying orientations and configurations. Deep learning networks like CNNs are valuable for both identifying pedestrians and classifying their actions.

Vehicle Detection :

Vehicle detection in ADASs focuses on identifying vehicles by common features like tires, brake lights, and license plates. These features distinguish vehicles from other objects. Deep learning networks such as CNNs aid in vehicle detection, considering various orientations and classes like cars, trucks, and semis.

Sign Detection :

ADASs increasingly support traffic sign detection, often used for determining speed limits. Techniques involve color thresholds to locate signs and optical character recognition to decipher their content. CNNs and hybrid techniques are also utilized for sign detection.

Lane Detection :

Lane keeping assistance, a feature in some production vehicles, aims to keep the vehicle within lane lines. Lane line detection is challenging due to inconsistencies like color variations and fading. Common methods involve Canny and Hough transforms to detect edges and determine if they form lane lines based on slope comaprison. CNNs are also increasingly used for this purpose.

The object(lane,vehicle,sign) detection

Collision Avoidance :

ADASs now integrate automatic braking and collision avoidance by leveraging various features like object tracking, vehicle detection, and distance estimation. By combining this data, vehicles can anticipate collisions and take preventive actions such as braking or steering to avoid accidents.

Environmental Impact

ADAS and autonomous vehicles have the potential to reduce fuel consumption and emissions through optimized driving patterns and vehicle efficiency improvements. The adoption of electric and alternative fuel vehicles, facilitated by ADAS technologies, can further contribute to environmental sustainability. Studies estimate that widespread adoption of ADAS and autonomous vehicles could significantly reduce greenhouse gas emissions and mitigate the environmental impact of transportation.

Impact of ADAS on Insurance

ADAS technologies such as automatic braking and lane departure warning systems, have demonstrated significant potential in reducing the frequency and severity of accidents on road.Studies have shown that vehicles equipped with ADAS features experience fewer collisions, resulting in reduced insurance claims and lower premiums for drivers. Insurance companies are beginning to recognize the benefits of ADAS and may offer incentives or discounts for vehicles equipped with these safety features.

Accessibility and Inclusivity

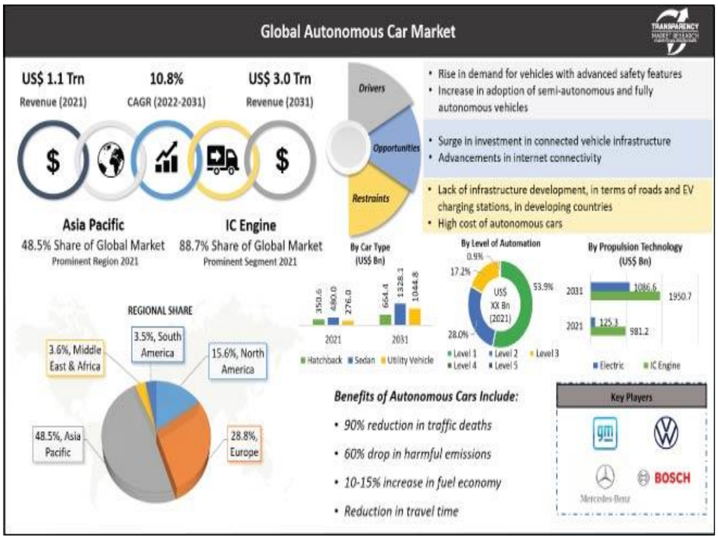
Designing ADAS technologies with accessibility in mind is essential ensuring that all drivers, including these with disabilities, can benefit from these safety features. Features such as voice commands, tactile feedback, and customizable interfaces can accommodate diverse user needs and preferences. Initiatives to promote accessibility and inclusivity in ADAS and autonomous vehicle design aim to create a more equitable and inclusive transportation system for all individuals.

INDOOR MONITORING

A study by the National Highway Traffic Safety Administration found that 80% of accidents are caused by driver fatigue, drowsiness, or distraction. ADAS in vehicles now focuses on monitoring drivers using cameras, alerting them if they're distracted or not looking at the road. Systems can detect drowsiness and fatigue, alerting drivers through seatbelt vibrations and speaker alerts.

NEXT GENERATION ADASs

Next generation ADAS solutions are beginning to use sensor fusion and other advanced communication systems, such as vehicle-to-everything(V2X).



Sensor Fusion

Sensor fusion combines information from multiple sesors to provide a single, accurate estimation of the environment's state. It helps overcome individual sensor limitations and improves precision, reliability, robustness, crucial for safety-critical systems like vehicles.Despite increased computational costs, modern car's computing power and declining sensor costs are facilitating widespread integration of sensor fusion systems. Recent interest in deep learning and other ML methods is driving research towards more efficient techniques to enhance ADASs with sensor fusion capabilities.

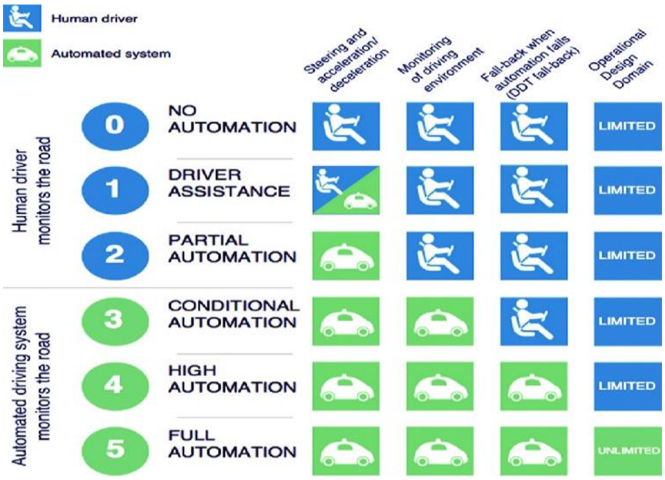
V2X Communication

V2X communication enables vehicles to exchange information with other systems in the environment for various purposes like collision avoidance and traffic updates. Examples include V2V, V2I, and V2P communications. It is facilitated by either dedicated short-range communications(DSRC) or cellular networks. The IEEE 1609 family of standards, based on IEEE 802.11p, defines an architecture for secure V2V and V2I communication using DSRC.

Modern vehicles are becoming increasingly connected with a lot of different systems, such as Wi-Fi, near-field Communication, and V2X.

Autonomous Vehicles

Next generation ADAS systems, integrating sensor fusion and V2X communication, are paving the way for autonomous driving. The SAE J3016 standard defines six levels of driving automation for on-road vehicles. Level zero vehicles have no ADAS assistance, while level one and level two vehicles offer partial assistance with steering or acceleration/deceleration under certain conditions. Level three vehicles, exemplified by models like the 2016 Tesla Model S, handle multiple safety systems but require driver intervention. Level four vehicles operate with more autonomy across various environments, while level five represents full autonomy without any human intervention. Achieving level five requires advancements in sensor technology, computing systems, and automotive networks.



SAEJ3016 levels of driving automation

Human-Machine Interaction

Effective human-machine interaction interfaces are essential for ensuring driver engagement and safety in ADAS and autonomous vehicles. Intuitive interfaces, clear feedback mechanisms, and adaptive features can enhance user experience and build trust in automated systems. Design principles such as simplicity, consistency, and user-centered design are crtical for designing interfaces that meet the needs of diverse drivers.

CHALLENGES

Changing Environmental Conditions

Todays ADAS faces challenges in performance due to changing environmental and weather conditions. Vision-based systems struggle in rainy or extreme lighting conditions. Sensor fusion is a possible solution, utilizing data from multiple sensors depending on weather conditions. For instance, using camera and radar in low light, and camera and lidar at other tomes for accurate distance estimation. Integrating V2I and developing cost-effective smart roads could further address this issue.

Resource Constrained System

Embedded systems in ADAS require low power consumption due to running complex algorithms, which consume significant power and produce heat. With limited energy availability in vehicles minimizing power consumption is crucial. This is achieved by using energy-efficient hardware like graphics processing units, digital signal processors, and image signal processors customized for ADAS applications. Additionally, ADAS embedded systems operate in real-time with strict timing constraints, requiring optimized hardware and software to minimize latency while maintaining low power consumption and predictable performance.

Security

As modern vehicles become more connected with systems like Wi-Fi, near-field communication, and V2X, they gain access to a wealth of information but also become vulnerable to cyberattacks. Numerous vehicle hacks have been demonstrated, highlighting the importance of securing both in-vehicle networks and external communication. For instance, researchers have used onboard diagnostics to hack GM vehicles and compromised the telematics system of a Jeep Cherokee to control acceleration, braking, and engine function. This security concern is heightened in ADASs and autonomous driving systems, making prevention of unauthorized access a top priority.

Geospatial Constraints

Many of the modern ADAS solutions being developed are tested within a geographic location or a group of locations where they are sold. This limits the ADAS to one or a certain group of geographical locations. This is because not all countries (or some states in a country) andhere to the same sign and road conventions uniformly , which makes ADAS algorithms that are often trained under one location hard to work efficiently in other locations. There is a need to improve algorithms , eg. exploiting V2X technology deployments to overcome variations in road sign conventions.

Human Factors in ADAS design

Human factors play a crucial role in the design and acceptance of ADAS technologies.User interface design, driver behavior adaption, and trust in automated systems are key considerations. ADAS systems should be intuitive and user friendly to ensure that drivers can effectively interact with and understand the information provided by the technology. Research has shown that addressing human factors leads to higher levels of trust and acceptance of ADAS technologies among drivers, ultimately improving safety outcomes on the road.

Data Privacy

The collection and storage of sensitive driver and vehicle data in ADAS and autonomous vehicles raise concerns about data privacy and security. Cybersecurity threats, such as hacking or unauthorized access to vehicle systems, pose significant risks to driver safety and personal information. Measures such as encryption, authentication, and secure communication protocols are essential for safeguarding data privacy and protecting against cyberattacks.

Regulatory Landscape

Governments and regulatory bodies play a crucial role in establishing safety standards and certification requirements for ADAS and autonomous vehicles. Regulations vary by region, with some countries implementing specific guidelines for testing and deployment of autonomous driving technologies.Ongoing developments in regulatory frameworks aim to address safety concerns and promote the responsible development and adoption of ADAS technologies.

CONCLUSION

In conclusion, this paper highlights the diverse range of ADAS variants and the critical role of sensors in their operation. ADAS systems are categorized based on sensors types and explored their applications in both outdoor and indoor environments, with a particular focus on vision-based ADASs. Additionally, emphasized the significance of sensor fusion techniques and advanced communication systems like V2X in paving the way for emerging autonomous vehicles.

However, several unresolved challenges persist in the realm of ADAS technology. Addressing these challenges will be crucial for the advancement and widespread adoption of ADASs. These challenges include enhancing system performance in varying environmental conditions, improving cyber security to prevent potential vehicle hacks, and optimizing power consumption for energy-efficient operation. Furthermore, ensuring regulatory compliance and addressing ethical considerations surrounding autonomous driving are essential aspects that require further attention.

Autonomous driving raises ethical dilemmas related to decision making in critical situations, such as the trolley problem where the vehicle must choose between two undesirable outcomes. There are also liability issues to consider, particularly in case where accidents occur while the vehicle is operating in autonomous mode. Ethical frameworks and programming decisions in autonomous vehicles must prioritize safetyand minimize harm while adhering to legal and moral principles.

Overall, while ADASs have made significant strides in enhancing vehicle safety and convenience, ongoing research and innovation are necessary to overcome existing challenges and realize the full potential of autonomous driving technology.

References

1)World Health Organization. (2015). Global status report on road safe- ty. WHO. Geneva, Switzerland. [Online]. Available:http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/

2) B. Markwalter, "The path to driverless cars," *IEEE Consum. Electron. Mag.*, vol. 6, no. 2, pp. 125–126, 2017.

3) P.Morignot, J. P. Rastelli, and F.Nashashibi,"Arbitration for balancing control between the driver and ADAS systems in an automated vehicle: Survey and approach," in *Proc. IEEE Intelligent Vehicles Symp.*, 2014, pp. 575–580.

4)F. Parada-Loira and J. L. Alba-Castro, "Local contour patterns for fast traffic sign detection," in *Proc. IEEE Intelligent Vehicles Symp. (IV)*, 2010, pp. 1–6.

5)M. I. Chacon-Murguia and C. Prieto-Resendiz, "Detecting driver drowsiness: A survey of system designs and technology," *IEEE Consum. Electron. Mag.*, vol. 4, no. 4, pp. 107–119, 2015.

Acknowledgments

"Acknowledgment(s)" is spelled without an "e" after the "g" in American English.

As you can see, the formatting ensures that the text ends in two equal-sized columns rather than only displaying one column on the last page.This template was adapted from those provided by the IEEE on their own website.