A Comprehensive Review Paper on Computer Vision Applications in Electric Vehicles Using Artificial Intelligence

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Abstract:

The integration of electric vehicles (EVs) with artificial intelligence and its advanced technologies is reshaping the automotive industries, with enhancing the capability, features, efficiency, improving safety and user experience. The key applications of computer vision such as autonomous navigation, focusing on object detection, lane detection, and advanced driver assistance system (ADAS) and energy management are discussed. With use of computer vision technique and AI (deep learning) algorithm, electric vehicle can accurately detect objects, including cars, motor bikes, pedestrians and cyclists that enabling the vehicle respond sophistically. AI's capacity to emulate human cognition spans a spectrum of industries, from rudimentary tasks to intricate decision-making processes[1]. And, the paper aims to cover various applications that shows the contribution of AI in electric vehicle to shaping future of intelligence electric vehicles.

Keywords: *Vehicles, Computer vision, electric vehicle, IoT, Advanced driver assistance systems, ADAS, , EVs*

Introduction:

Electric vehicles is rapidly reshaping the automotive industry by critical shift towards sustainable transportation solutions which driven by environmental concerns and technological advancements. Computer vision is a multidisciplinary approach with the integration of Artificial Intelligence into electric vehicle is driving the next wave of automotive innovation. These technologies enable Electric vehicles to understand, perceive, and interact with their surrounding efficiently. There are some of the key applications of computer vision in electric vehicles such as autonomous driving, driver assistance system, park assist to solve parking solution without human intervention, surrounding view monitoring, energy efficiency and route optimization, pedestrian and cyclist detection, facial recognition for access control, augmented reality dashboards, smart head lighting , adaptive lighting and fleet management that helps Electric vehicles navigate the world in a safer and smarter way, to make this possible the algorithm process images and videos captured by cameras often in combination with other sensors like LiDAR , radar, and ultrasonic sensors to make real-time decision about the vehicle movements. Some of the primary computer vision algorithm used in Electric vehicles are **YOLO, Faster R-CNN, SSD, RetinaNet, Stereo vision, LiDAR, SFM, SSD, Deep learning, CRF, and other, are** used to make driving safer. Artificial intelligence starts by calculating emissions from automobiles in order to conjecture and aim to configure the system to reduce emission. There are various factors like time, efforts, distance, fuel type, etc., that can estimated the amount of CO2 released by self-guided vehicle can determine the most efficient and economical way to reduce emissions, and companies may use this information to develop better, more energy-efficient vehicles[1] [2,3].

Fundamental of Computer vision and Artificial Intelligence:

Computer vision is a subset of artificial intelligence (AI) that enlist machine learning and neural network to enable system to comprehend from computerized images, videos and other visual data inputs. It enables them to see, observe, understand and make judgements based on visual information. Computer vision process similar to human visual system, such as recognizing objects, detecting patterns, interpreting and understanding the context of images.

To perform this procedure, we have 3 steps:

1) Acquire data in the form of image or video using camera and other device.
2) Modify these data by resizing, cropping, or filtering the image with the help of some pattern recognition algorithm for best results.
3) Finally, machine learning algorithms recognize pattern, objects, and features in images.

Artificial intelligence in Electric Vehicles:

The larger historical context in which AI powers EVs has long been linked to the development and tremendous progress of AI technologies, such as those diligent in transport networks. Research projects in the early 20th century laid the groundwork for the development of AI in transportation, particularly as it relates to EVs. The basic rule-based control algorithms that were first studied in these projects aimed to increase the autonomy and control of vehicle operations—a goal that contemporary AI technologies have since pursued. These early attempts offered crucial information and enabled this work, even though their resemblance to modern AI systems pales in comparison to current capabilities.

As AI algorithms and computing power have advanced over time, more complex control systems have been able to be installed in EVs, improving their performance, safety, and autonomy through the integration of AI algorithms, machine learning techniques and neural networks algorithms. The automotive sector strove hard to build AI and control-based systems for autonomous and connected vehicles, or Center for Advanced Vehicular Systems (CAVs).[4] [5]. The advancement of AI technology in EVs is fuelled by improvements in processing power and the understanding of AI algorithms. EVs may now achieve previously unheard-of levels of efficiency, safety, and autonomy thanks to machine learning techniques, deep learning algorithms and neural networks algorithms,
As a result, AI algorithms have improved the utility and consumer-friendliness of EVs by employing data-driven techniques to anticipate energy consumption, simplify route planning, and determine the best charging stations.

Literature Review:

K.Balaji Nanda kumar Reddy, D.Pratyusha,E.Jayakiran Reddy, B.sravanthi(2024): This paper comprehension of the enduring digitalization and electrification of transportation, and integration of Artificial intelligence and innovation in vehicles give tremendous potential to automobile industries towards organic mobility solution and minimize environment effects of vehicle emissions. The goal of this paper to show the contribute of AI in EVs and its effects like AI technologies such as neural networks and machine learning support cognitive decision making, predictive analytics, sophistic driving assistant and self-reliance vehicle in EVs, all of which contribute to a trustworthy, environmentally responsible, protected and crazy driving experience with environment benefits with minimize release of greenhouse gas and improved air purity.

Deepali Virmani,Abdelbasset barkat,Dr. Lalit Mohan Trivedi,Dr. B Jaison, Dr.P. Kalarani,Bhabani Sankar Gouda(2024): This article tell us about significant benefit of CNN technology in electric vehicles that turned into an incredible asset of AI. It explores some of AI techniques and methodologies that give computer vision to new height.

Soosan Chhabra,V. Sreevani (2024): In order to achieve the goals of enhancing station capabilities, optimization resource utilization, and improving user experiences, this paper investigates the integration of computer vision technologies into intelligent electric vehicle charging infrastructure. And also explore the potential benefits and barriers of applying computer vision technology to the creation of user-centered ,wise EV charging infrastructure.

Kapileswar Rana, Narendra Khatri (2024): This paper gives understanding about various uses of AI and machine learning in automobile industry. It highlighted how Artificial Intelligence is affecting connecting vehicles, security, vehicle emissions and driver monitoring systems. Technical approaches like ANN, SVM and bee colony are used in vehicle security to provide effective and fast decision making to protect vehicles from intrusion. Using wavelet theory and Fourier transformation, reinforced learning combined with machine learning improves the vehicles predictive maintenance. Models like SDN-FoG computing and XAI model use to safe data transfer and communication between vehicles.

Key applications of computer vision technique employed in Electric Vehicle:

Computer vision (CV) is a critical technology utilized in electric vehicles for improvement them that is being revolutionized by artificial intelligence (AI). AI is changing the EV ecosystem in various ways, from increasing improving vehicle performance to user experience. Key application of AI in electric vehicles include the following:

1. Personalized User Experience: Personalization mean customization according to your desire. In vehicles, traditionally personalization mean modification in seat belt and mirrors. Now, EVs have two primary area i.e. the driving performance and the driver assistance systems personalization. In this system focus on driving experience to individual preference,

needs, habits, styles that can make driving more comfortable and enjoyable. Ways to enhance personalized experiences are Customized Driving Settings, Facial Recognition & Biometric Authentication, Adaptive UI And Voice Assistant, Safety Features and Assistance Systems(Adaptive Cruise Control & Collision Avoidance, Driver Behaviour Monitoring), Personalized Software Updates, Sustainability Preferences(Eco Mode and Energy Efficiency Tracking) etc.

2. Object Detection and Recognition: The ability to recognize appearance of visual thinks of specific categories (such as human being, animals, vehicles, pedestrians, cyclists, or buildings) in digital images like video frames or picture is an important computer vision task to improve safety. The most basic information required for computer vision applications is to give answer of question i.e. "What objects are where?", and object detection aims to create computational models for those objects that supply it. Use of convolutional neural networks (CNNs) for real-time image analysis. Thinks like car, person, bicycle, and handbag are detected in figure 1.

Fig. 1 Things recognized with the help of computer vision (Source: Viso Suite)

3. **Vehicle Battery Management:** It is a crucial system that guarantees the efficient and safe mechanism of the battery pack, which is heart of an electric vehicle. The Battery Management System (BMS) is assigned to monitoring the battery's condition, functionality, overseeing health, performance, and longevity, optimizing energy usage, and preventing potential issues such as overcharging or overheating. Here's a detailed look at how battery management works in EVs. An electric vehicle's battery pack's voltage, temperature, state of charge (SOC), and state of health (SOH) are all monitored and managed by battery management system (BMS), which is a hardware and software combination. The BMS makes sure that the battery runs effectively, safely, and within its designed operating conditions.

4. Vehicle Security: Protection of both vehicle and battery system is very crucial. As EVs are equipped with advanced technologies like connectivity, automated systems, and sophisticated battery management, securing these systems becomes even more complex and important. Vehicle security in EVs focuses on a range of measures to ensure the safety of the vehicle, its occupants, and its sensitive components.

Some of the vehicle security types are:

- **Physical Security**: Introducing features like Keyless entry system(without putting key, drivers can get into and start their vehicle),steering wheel locks or brake pedal locking systems and charging port security can ensuring protection by physical theft, hacking and unauthorized access.
- **Battery Security**: Introducing features like BMS security (regulate power flow and protects the battery from dangerous condition like overheating, overcharging and short-circuit by BMS lock), physical protection of battery pack by equipping with sensors, that detect unauthorized attempts.
- **Cybersecurity**: The connection of electric vehicle by network and internet, the feature like vehicle-to-everything (V2X) security, telematics and over-the air (OTA) updates, Remote vehicle control security, and advanced Encryption and firewalls by preventing hacking, remote control of the vehicle and unauthorized data access.

5. Real Time Vehicle Emissions monitoring: Mainly concerned with understanding how EVs affect the environment indirectly, especially with relation to the energy required to charge them and the carbon intensity of that power. Customers, fleet managers, and policymaker may use this information to make well-informed decisions that will further lower EVs' overall carbon footprint and aid in the worldwide fight against climate change. **Tesla** provides real-time feedback to users on their energy consumption and carbon footprint.

Some of the key areas for real-time emissions monitoring in Electric Vehicles include Energy Consumption and efficiency tracking, Indirect Carbon Emissions from Electricity Grid, Vehicle-to-Grid (V2G) and Emissions Balancing, Emissions during Charging.

6. Vehicle to vehicle communication: V2V communication enables **direct wireless communication** between vehicles(V2V), vehicles and infrastructure (V2I), and even vehicles and pedestrians (V2P) allowing them to exchange information such as speed, location, direction, and status. This communication relies on **Dedicated Short Range Communication (DSRC)** or **Cellular-V2X (C-V2X)** technologies to transmit data in real-time. V2V can also be integrated with other technologies like radar, cameras, and GPS for comprehensive situational awareness. Some of major advantage are Enhanced Safety and Collision Avoidance, Blind spot detection, Efficient Real-time Traffic Updates, Battery Consumption and Regeneration, and Autonomous Driving and Self-driving EVs.

7. **Vehicle control**: Electric Vehicle performance is becoming better day by day with involvement of Artificial Intelligence. Major problem of driver mental load, tiredness and behaviour can be overcome by the characteristics such as lane keeping assistance, automatic parking and adaptive cruise control. Monitoring driver behaviour and attention using facial recognition and gaze tracking to make decision and take necessary action to ignore accident situation and ensure safety. It has been suggested that advanced control algorithms that use real-time sensor data and predictive analytics reduce power consumption and improve driving safety and comfort [7]. OpenCV and diamond searching technique is used to recognize Eye and Facial expression. A wide variety of sensors, comprising LiDaR, Radar, and cameras, are used by Adaptive Cruise Control System to keep an eye on traffic conditions. To maintain a safe distance between cars travelling down the road, the ACC system can adjust the vehicle's speed and compute the distance between two vehicles based on these data.

Some of the applications used for making safer journey in roads:

1. To make driving safer and more convenience overall, **Tesla** uses Autopilot and full self-driving (Supervised) mode. Tesla's Autopilot considered two main features Traffic-Aware Cruise Control and Auto steer. Tesla's Autopilot employs AI for advance driver assistance system to reduce your overall workload as a driver. To reduce human error Tesla car has advanced visual processing and exterior cameras. Tesla's full self –driving mode include feature such as navigation, automatic lane changes, automatic parking, mobilizing and traffic signal and spotlight control.

2. The Advanced Driver Assistance System (ADAS) OF the NIO ET7 use AI to identify moving things to prevent collisions and then apply the EM brake.

8. Sustainability and Environment Impact: The innovation in automotive industries in electric vehicle sector proven a boon for environment .They assist with the lack of natural resources. It is important to observe the environmental damage caused by destruction of habitat, water contamination, and disruption of ecosystems in the energy intensive operations of fossil fuel extraction, refinement, and transportation [4]. Expansion of CO_2 emission by various sectors in India since 2000 is shown in figure 2.

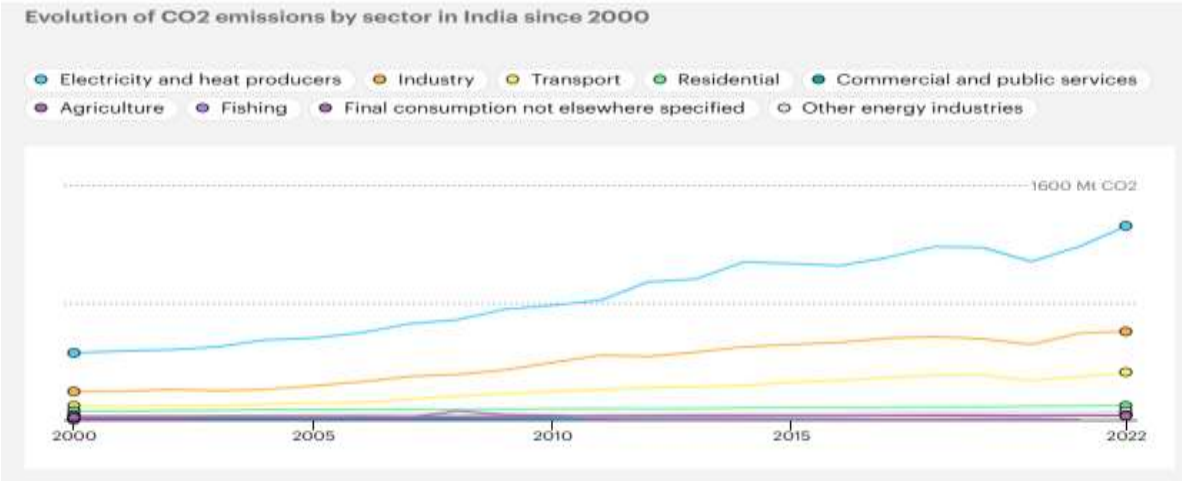

Fig 2. Expansion of CO2 emission by various sectors in India since 2000 (Source: India Environment Agency (2022))

9. Autonomous Navigation: Use of advanced technologies that allow an EV to navigate and drive itself with minimal human intervention. For real-time judgment of the surroundings, decision making, and vehicle control, these AI technologies rely on a variety of sensors, ML models, and software algorithms. EVs with autonomous navigation have the potential to be safer, more convenient, and more economical. AVs, or Autonomous vehicles depend on an assortment of hardware (sensors) and software (algorithms) to achieve self-driving capabilities Sensors are used to perceive the environment around the vehicle and provide data for decision-making. Common sensors in autonomous EVs includes LiDaR (Light Detection and Ranging) sensor, ultrasonic sensors, and cameras, Radar, GPS and IMU (Inertial Measurement Unit). The data from these sensors is processed by advanced software that makes decisions about the vehicle's path, speed, and manoeuvring. Key software components include Perception Systems, Localization Algorithms, Path Planning, and Control Systems.

Conclusion:

This paper explore the various applications of artificial intelligence in electric vehicle that give shape to the future of automotive industry. Some of key applications such as autonomous driving, driver assistance system, park assist to solve parking solution without human intervention that helps Electric vehicles navigate the world completely autonomous, intelligent, safer, eco-friendly and sustainable transportation systems due to the increasing convergence of Artificial intelligence, computer vision, and electric vehicle technology.

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