

Cloud Computing-Based Vehicle Image Recognition Systems for Intelligent Traffic Management: A Systematic Review

Veerendra Kumar Sen^{1*}, Yatendra Kashyap²

Research Scholar, Computer Science, SAM Global University, Bhopal, Madhya, Pradesh,
India

vksen9754@gmail.com

2 Dean Engineering, SAM Global University, Bhopal, Madhya, Pradesh, India

Abstract: Urbanization, more vehicles on the road, and the resulting congestion have posed huge problems for transportation authorities in ensuring efficient and safe traffic control on the roads. The recent development of cloud computing and artificial intelligence technologies has paved the way for the creation of intelligent traffic management systems that can handle and analyze massive amounts of vehicle image information in real time. This systematic review summarizes the existing work performed on cloud computing based vehicle image recognition system for intelligent traffic management and highlights the status of research on cloud computing architectures, computer vision techniques and machine learning algorithms. It examines the development of the vehicle image recognition technologies, such as the convolutional neural networks, object detection models, and deep learning frameworks, and their integration with cloud platforms for scalable and high-performance traffic monitoring applications. In addition, it examines the benefits of edge computing, IoT devices, and distributed cloud systems for boosting processing power, minimizing latency, and increasing system reliability. It also covers important application areas like incident detection, congestion prediction, traffic flow analysis, licence plate recognition, vehicle detection and classification. It also highlights key areas of concern for data privacy, cyber security, computational expenses, interoperability, and real-time performance. Last but not least, the study points out the existing research gaps and further directions to improve the secure, scalable, and intelligent design of vehicle image recognition systems in the cloud for sustainable urban mobility and next-generation smart transportation infrastructures.

Keywords: Cloud Computing-Based, Vehicle, Image Recognition, Intelligent Traffic Management

1. INTRODUCTION

The growth of cities and the never-ending rise in the volume of automobiles is a strain on transportation systems around the globe like no other. Governments and transportation authorities are faced with big concerns, such as traffic congestion, road accidents, environmental pollution, and inefficient traffic monitoring. However, the traditional traffic management systems are mainly based on fixed traffic control and manual monitoring, which

are often not suitable for dealing with the dynamic and complex traffic environment. For this reason, development of Intelligent Transportation Systems (ITS) is increasingly an important part of the work required to make roads safer and more efficient, and to optimize their traffic flow. The new technologies that enable ITS are cloud computing and vehicle image recognition, which can process vast amounts of traffic data and provide support to make real-time decisions (Jadhav, S. 2022).

Cloud computing provides flexible service delivery, high-capacity data storage and scalable computing resources in distributed computing environments. These are also the features that allow transportation agencies to ingest, store, process, and analyze huge quantities of vehicle image and sensor data without having to invest in costly local infrastructure. At the same time, the development of artificial intelligence, machine learning and deep learning has transformed the field of vehicle image recognition, which is now fully capable of automatic detection, classification, tracking and identification of vehicles with very high accuracy. However, with the advent of modern computer vision algorithms such as convolutional neural networks, and real-time object detection models, the performance of traffic surveillance systems has greatly enhanced in different environmental conditions.

This combination of cloud computing and image recognition for vehicles has led to a new class of intelligent traffic management systems that can enable the monitoring of traffic flow, predict traffic congestion, detect traffic incidents, identify vehicle license plates, optimize traffic signals and enforce road regulations in real-time. In addition, with the advent of edge computing and IoT, cloud-based systems have become more efficient, processing data at the edge has significantly reduced communication delays, and the overall reliability of the system has improved. The use of these technologies helps achieve smart city goals by enabling urban planning and management to be based on data (Yousef, M. M. 2021).

Although there has been significant advancements in this area, there are still some technical and operational issues that plague the widespread adoption of image recognition systems in the cloud for vehicles. There are several questions about data privacy, cybersecurity, interoperability, network bandwidth, computational costs, and model scalability that need to be explored. This systematic review will, therefore, review the latest research on cloud computing-based vehicle image recognition systems for intelligent traffic control. It compiles the current literature in the fields of cloud architectures, image recognition techniques,

artificial intelligence models, and traffic management applications and aims to highlight gaps in research, trends, and future directions. This review will enable researchers, practitioners and policymakers to have a thorough overview of the latest developments and potential for secure, efficient and intelligent traffic management systems.

2. CLOUD COMPUTING IN INTELLIGENT TRANSPORTATION SYSTEMS

Cloud computing is one of the most impactful technologies that is helping to power the digital transformation of modern transportation systems. With the growing number of vehicles on the roads in cities, and a rising number of cities experiencing rapid urbanization, transportation authorities need advanced computing platforms that process huge amounts of real-time traffic data efficiently. ITS are based on the capability of collecting data from surveillance cameras, sensors, connected vehicles, Global Positioning System (GPS) devices and Internet of Things (IoT) devices in order to monitor traffic conditions and to aid decision making. Typically, storing such large volumes of data on traditional computing systems can be expensive, inflexible, and challenging to scale. Cloud computing overcomes these challenges by offering a centralized, scalable, and cost-effective platform for data storage, processing, and analysis in transportation applications. Thus, cloud computing is a crucial technological underpinning for smart transportation, for intelligent traffic monitoring, car image recognition, prediction analysis, and adaptive traffic management (Perez, P. 2019).

Cloud Computing is the computing paradigm that allows access to computing resources like servers, storage, networking, databases, software, and processing power that is shared to the users on-demand via the Internet. Instead of physical resources users are able to make use of virtualized resources as needed, and only pay for what is used. The flexibility of this model enables organizations to adjust the amount of computing power based on the needs of the specific workloads, thereby lowering the amount of equipment that needs to be purchased and maintained. Within the field of intelligent transportation systems, cloud computing serves as a centralized platform that brings together information from various traffic monitoring systems, facilitating the exchange of information in real time, centralized data storage, data analysis, and the coordination and management of traffic over a large geographic area.

3. VEHICLE IMAGE RECOGNITION TECHNOLOGY

Vehicle image recognition technology is one of the most crucial elements in today's Intelligent Transportation Systems (ITS). Over the last few years, the digital camera, Artificial

Intelligence (AI), computer vision and cloud computing have revolutionized the world of traffic monitoring and made it an automated and intelligent process. The recognition of vehicle images or face is a technology that can be used to detect, identify, classify, and track vehicles from images and video streams collected by surveillance cameras, Roadside Sensors, drones, and smart monitoring devices. This technology has a great relevance to traffic management, road safety, law enforcement, congestion monitoring, toll collection, parking management, and smart city development. Vehicle image recognition (VI) automatically extracts valuable information from visual data, which enhances operational efficiency, supports real-time decision making in transportation networks, and minimizes the human effort required (Caruntu, C. F. 2024).

Digital image processing is the basis for vehicle image recognition and describes the manipulation of digital images with computer algorithms for enhancing, analysing and interpreting them. Digital image processing converts visual information into numerical data that can be processed by computers. A digital image comprise thousands of millions of pixels and each pixel has intensity and colour information. The main goal of digital image processing is to enhance image quality and to extract meaningful information which can be further analyzed. Typically, image processing workflow starts by acquiring images from a traffic scene using a camera or sensor to take photos or video frames. The images that are acquired to be recognized often have noise, poor illumination, shadows, weather effects or motion blur, which can compromise the accuracy of the recognition. Hence, suitable pre-processing like image enhancement, noise filtering, histogram equalization, contrast adjustment and image normalization are used to enhance the image quality. The image is preprocessed to extract the regions of interest, which are then used for vehicle segmentation. The feature extraction techniques then extract the edges, corners, texture, color, and shape of the objects which assists in differentiating the vehicles from other objects. Last, classification algorithms are used to classify vehicles with high accuracy based on these extracted features. These image processing methods are the basic framework for advanced vehicle recognition systems.

One such significant progress in image analysis has been the advent of Computer Vision, which allows computers to interpret and understand the visual world in a similar manner as humans. Computer vision is a field that integrates image processing, pattern recognition, AI, and machine learning to automatically analyze images. Unlike conventional image processing which mainly concentrates on the quality enhancement of images, computer vision is designed

to recognize objects, to understand the scene and to make intelligent decisions based on the visual input (Yang, Y. 2022).

4. TRAFFIC CONTROL AND SMART TRANSPORTATION

Traffic control is a crucial aspect of an integrated transportation system for safe, efficient, and orderly movements of vehicles and pedestrians in road networks. With the growth of urban population and the exponential rise in the number of vehicles, traffic management is getting complicated. Conventional traffic management techniques, mainly relying on fixed infrastructure and manual management, struggle to deal with the complexity of traffic flows. As a result, the digital technologies' advancements have resulted in the development of smart transportation systems that combine information and communication technologies, artificial intelligence (AI), cloud computing, Internet of Things (IoT), and data analytics to enhance traffic management. Smart transportation is about maximizing traffic flow, minimizing congestion, making roads safer, reducing environmental impacts, and making trips better (Zhang, Y. 2020). Today's transportation systems are intelligent, adaptive, efficient, and responsive to traffic conditions through their intelligent monitoring systems and automated decision-making. In the past, traffic management systems were based on manual traffic management, fixed-time traffic signals, road signs and traffic police enforcement. The idea behind these systems is to control vehicle motion according to a fixed traffic flow and past experience. The traffic lights were operated by fixed time schedules, or traffic officers would stop traffic during times of peak usage and emergencies. Subsequent additional surveillance cameras and inductive loop detectors were added to monitor vehicles and aid traffic operations. These traditional systems contributed significantly to the enhancement of transportation efficiency in relatively low traffic flow, but had some drawbacks (Li, K. 2021).

The traditional traffic management systems have a number of drawbacks, such as the inability to respond to the rapidly changing traffic conditions. Fixed traffic signal durations can not adjust effectively to varying traffic flow conditions of peak hour periods, construction on the road, accidents, public events or bad weather. This causes unnecessary delays for vehicles, even if there is little cross traffic. Manual traffic control also demands a lot of manpower and is prone to human error, fatigue, and erratic judgment. Moreover, conventional monitoring techniques give limited current information, which makes it hard for traffic control authorities to monitor traffic incidents quickly or optimize traffic flow on a large metropolitan system.

Such challenges have brought the necessity of intelligent transportation technologies with dynamic traffic management to the fore. The advent of intelligent traffic monitoring has revolutionized the way transportation systems monitor and manage the condition of their roads. Intelligent traffic monitoring is the process of collecting, analyzing, and interpreting transportation data continuously by means of advanced sensing technologies, surveillance cameras, computer vision, artificial intelligence and communication network. Smart monitoring provides real-time visibility across transportation networks, unlike traditional monitoring which can only give limited observations (Alavi, A. H. 2021).

HD surveillance cameras, vehicle detectors, GPS, connected vehicle, mobile apps, radar sensors, LiDAR systems, and Internet of Things (IoT) devices are all sources of data for modern traffic monitoring systems. These technologies constantly assess traffic volume, vehicle speed, lane occupancy, travel time, congestion, pedestrian movement and road condition. The computer vision and image recognition algorithm automatically identifies the vehicles, categorizes vehicle types, calculates the traffic density, detects traffic violation and detects abnormal driving behavior. Real-time monitoring allows transportation authorities to detect incidents as they happen, providing them with the ability to respond quickly to accidents, road closures or unexpected congestion. Another significant application of artificial intelligence in intelligent traffic monitoring involves analyzing traffic patterns and forecasting future traffic conditions. Machine learning algorithms analyze historic and real-time transportation information to predict congestion, estimate traffic demand, identify unusual traffic patterns, and suggest traffic management strategies. The predictive tools allow transportation agencies to take proactive steps instead of reactive measures when traffic problems arise. As a result, smart monitoring systems have an enormous positive impact on operational efficiency, road safety and travellers' convenience. (Houlsby, N. 2021).

5. INTERNET OF THINGS (IOT) IN INTELLIGENT TRAFFIC MANAGEMENT

Internet of Things (IoT) is one of the most promising and impactful technologies in today's transportation systems. With the ongoing urbanization and growth of vehicle numbers in cities, traditional traffic management techniques are proving to be inadequate to deal with the complexity of modern infrastructure networks. The Internet of Things (IoT) technologies are playing a more prominent role in Intelligent Transportation Systems (ITS), where they gather, send and analyze real-time traffic data in order to enhance road safety, mitigate congestion

and improve the efficiency of transportation. In IoT, physical devices like traffic sensors, surveillance cameras, connected vehicles and roadside infrastructure can communicate with each other and with cloud-based platforms via communication networks. This integrated supply chain offers road authorities real-time visibility of road conditions to enable intelligent and timely action. The combination of IoT and other technologies such as cloud computing, Artificial Intelligence (AI), Machine Learning (ML), and computer vision has greatly improved the performance of smart traffic management systems and is an important part of smart city development (Sarkar, R. 2024).

The Internet of Things (IoT) is the term used for a network of physical devices featuring sensors, communication modules, processors, and software that are able to collect, share, and analyze data with each other and the Internet without the need for constant human oversight. IoT devices can sense the environment around them, produce data, and share the information with other connected devices or centralized computing systems. Imagine a transportation system where cars and roads, traffic lights, surveillance cameras, parking lots, weather stations, and mobile apps all constantly share data with one another. In transportation systems, IoT can be the digital ecosystem that makes it possible for cars and roads, traffic lights, surveillance cameras, parking lots, weather stations, and mobile applications to constantly communicate with each other. This seamless communication enables transportation authorities to have a real time view of traffic conditions on the network and deploy intelligent control strategies in response to real time road conditions. Continuous connectivity between geographically dispersed devices is one of the hallmarks of IoT technology. To connect traffic monitoring devices to cloud platforms to maintain reliable communication between the systems, wireless communication technologies like Wi-Fi, Bluetooth, ZigBee, Radio Frequency Identification (RFID), Near Field Communication (NFC), cellular networks, Fifth Generation (5G) communication, and Low Power Wide Area Networks (LPWAN) are being used in modern IoT systems. The technologies allow for vast amounts of real-time information to be gathered and the transmission of information to be extremely quick, covering great distances. The scalability and flexibility of IoT networks are well suited for intelligent transportation systems within large metropolitan areas (Seitz, J. 2021).

One of the major uses of IoT in transportation is the use of IoT sensors and smart cameras in traffic. Traffic sensors are placed at various areas like urban roads, parking facilities, highway, tunnels, intersections etc to continuously track road conditions and vehicle flow. The types of

sensors covered are inductive loop, infrared, ultrasonic, radar, LiDAR, magnetic, environmental and vehicle counting. They monitor different aspects of transportation like vehicle speed, traffic volume, lane occupancy, travel time, road surface conditions, temperature, humidity, and weather conditions. Smart cameras are one of the most advanced devices in the IoT field used for smart traffic control. Smart cameras are different from traditional surveillance cameras as they have embedded processors with artificial intelligence and computer vision abilities that allow the automatic analysis of the images captured. The cameras are able to identify vehicles, read license plates, identify vehicle types, estimate traffic volume, monitor lane discipline, detect traffic offenses, and detect accidents without the need to manually observe. Certain smart cameras also include edge computing capabilities, which enable initial image processing to take place locally, while only passing on key data to the cloud. It decreases the communication bandwidth requirement and enhances the response time of real-time traffic management system (Wang, F. 2021).

6. BIG DATA ANALYTICS IN TRAFFIC MANAGEMENT

Intelligent Transportation Systems (ITS) have come to rely on Big Data Analytics for processing and analysing vast amounts of traffic-related information produced by the modern transportation infrastructure. Today the amount of structured and unstructured data generated by transportation systems grows exponentially as the population grows, people buy more cars, and the deployment of the Internet of Things (IoT) devices is vast. These rapidly increasing volumes of data cannot be efficiently processed using traditional data processing methods. Big Data Analytics tackles this challenge by using sophisticated computing techniques to gather, store, process and analyze transportation information in real time. By combining Big Data Analytics with cloud computing, Artificial Intelligence (AI) and Machine Learning (ML), the traffic authority can take decisions based on facts, predict traffic, enhance road safety, and optimize transportation operations (Girshick, R. 2017).

Big Data is a massive amount of data that is too large and complex to be processed by traditional data management tools such as relational databases. It is often referred to as the 5Vs: Volume, Velocity, Variety, Veracity, and Value. Volume is the volume of data on transportation collected from surveillance cameras, traffic sensors, GPS devices and connected vehicles. The speed of these data to be generated and continuously transmitted is known as velocity. The data in transportation can be in many different formats: images, videos, sensor

readings, GPS coordinates, weather data, traffic data, etc. There are many kinds of data in transportation, such as video, images, sensor data, GPS data, weather data, traffic data, etc. Veracity's main thrust is on the reliability, quality and accuracy of the data collected, which is essential for sound traffic management. Last but not least, Value is the application of valuable information learned from transportation data that enables intelligent decision making, congestion management, accident prevention, and infrastructure planning.

Big data originates from many sources scattered across road networks to form the basis of transportation systems. Traffic surveillance cameras are one of the main sources, as they are continuously capturing high-resolution images and streams of video that are used to detect vehicles, monitor traffic, and recognize license plates. Traffic sensors such as inductive loop detectors, radars, lidars, infrared and magnetic sensors continuously measure vehicle speed, traffic volume, lane occupancy, and road conditions, and enable the creation of an intelligent transportation system. Vehicle-to-vehicle communication (V2V) technology is like GPS (Global Positioning System), except that the information sent from private vehicles, public transportation, commercial fleets and smartphones continuously tells the location, speed and route of the vehicle. Vehicle-to-vehicle technology also collects valuable telematics data such as acceleration, braking, fuel usage, driving habits, and more.

7. SECURITY, PRIVACY, AND ETHICAL ISSUES

Intelligent Transportation Systems (ITS) are making a great leap forward with the widespread use of cloud computing, Artificial Intelligence (AI), Internet of Things (IoT) and vehicle image recognition technologies. The technologies involved can be used for real-time traffic monitoring, automatic vehicle detection, intelligent traffic control, congestion prediction and improved road safety. But as the use of digital technologies has grown, so have some key issues of data security, privacy protection, cyber security, ethics and legal compliance. ITS collect, process, store and transmit vast amounts of sensitive data, such as vehicle images, license plates, GPS locations, travel patterns, traffic videos, and personal mobility data, all the time. To preserve public confidence and to assure the long term implementation of smart transportation systems, these data must be protected from unauthorized use, while maintaining their ethical use. Hence, security, privacy and ethical issues are integral parts of cloud based image recognition in vehicles.

Data security in cloud computing is one of the main issues of ITS. Cloud computing enables centralized storage, scalable computing resources and real-time processing of transportation data. Cloud platforms while providing great benefits in operation, do also present possible security threats as transportation data is stored and processed on remote servers via the Internet. Unauthorized use of cloud infrastructure could lead to the disclosure of confidential information or compromise system operations and services, or disrupt critical transportation services. Transportation data encompass surveillance videos, vehicle registration numbers, traffic volume data, road network data, accident reports, and traffic management center operational traffic data. In the event of such data being misappropriated, the cybercriminal can alter traffic flow data, gain access to confidential information or disrupt intelligent transportation functions. Therefore, cloud service providers and transportation agencies will need to put in place a robust security framework to help secure cloud-based traffic management systems (Adam, H. 2017).

There are a number of security technologies that are part of the cloud data protection solutions. Data encryption transforms the data into an encrypted form when it is being sent or stored so that any data that is stolen or intercepted cannot be understood. The authentication systems such as passwords, multi-factor authentication, and biometric verification only allow access to authorized people. Access control policies identify users' permissions based on their organizational responsibilities, and they will not be able to alter transportation databases without authorization. Regular security audits, monitoring of systems, backup strategies, and disaster recovery plans are also crucial for securing the cloud environment by identifying vulnerabilities and maintaining service continuity. Information transferred between IoT devices, cloud servers and traffic management centers are also secured through the use of secure communication protocols like Transport Layer Security (TLS) and Virtual Private Networks (VPN). One of the other significant problems is privacy related to image recognition in the vehicle. Nowadays, intelligent transportation systems use surveillance cameras and computer vision systems to keep an eye on the traffic on the road 24 hours a day. They can automatically identify vehicle images, vehicle number plates and classify vehicles, calculate the speed of vehicles and trace their movement at multiple surveillance sites. These capabilities may enhance traffic management and help to protect public safety, but they also carry a number of privacy concerns (Yadav, R. K. 2020).

8. CONCLUSION

The fusion of powerful computer vision and AI capabilities with cloud computing has given rise to image recognition systems in vehicles, which are poised to change intelligent traffic control. The results of this systematic review show that the combination of cloud computing, deep learning, and image recognition has greatly improved traffic monitoring, vehicle detection, classification, and congestion management, providing a significant boost in the accuracy, scalability, and efficiency of these systems. The studies reviewed in this work suggest that cloud-based architectures can enable real-time processing of gigantic traffic data sets, allow for smooth storage and analysis, and assist in better decision-making for transportation companies. Moreover, the introduction of edge computing and IoT has decreased the response lag time and improved the responsiveness of smart transportation systems. While these improvements have been made, there are still some obstacles to be addressed, such as data privacy, cybersecurity, dependence on the network, interoperability, infrastructure costs, and the lack of an evaluation framework that is commonly accepted. To enable reliable and secure cloud-based traffic management solutions, it is crucial to address these issues. Further studies are needed on designing efficient cloud architectures, privacy-friendly machine learning approaches, explainable AI models, and hybrid edge-cloud systems to enable autonomous transportation and smart city ecosystems. In conclusion, the use of cloud computing in vehicle image recognition technology is a promising approach toward enhancing traffic management in rapidly urbanizing areas to become safer, smarter, and more sustainable.

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