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Managing Transport Systems with Artificial Intelligence

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Abstract

Problems caused by the growth of traffic in cities require modern management approaches to improve the situation with the routing of traffic flow. This article aims to develop a conceptual system that uses computer vision technology to collect and process data from vehicles. It describes the technology of computer vision as an opportunity to improve routing algorithms by processing large data streams that reflect real situations and causes that affect route optimization. The result of using the color vision system is to provide more accurate and timely information to drivers, allowing them to make informed decisions about their routes. This will reduce traffic congestion, improve transport efficiency, and minimize the negative impact on the environment.

Keywords: Computer Vision System, Intelligent System, Global Positioning System (GPS), Light Detection and Ranging (LiDAR).

Introduction

Over the years, the number of people and cars on public roads has increased, on average, the time spent by a person in motor vehicles, being in traffic jams. There is also increasing due to the obsolescence of urban approaches in cities and the imperfection of systems for processing the flow of cars and traffic.

There is an actual problem of urban congestion caused by a large number of cars (Computer Vision News, 2021; Modelling the Relationship, 2016). It is necessary to offer a solution that involves using a computer vision system to collect and process data from vehicles, ultimately optimizing route recommendations to reduce congestion (On-Line Network, 2023; Fuzzy Hierarchy Analysis, 2023; Planning Transport, 2023).

The main components of the proposed system include data collection using various sensors and cameras, real-time computer vision analysis for monitoring road conditions and detecting road accidents, as well as predictive algorithms to offer drivers alternative and more efficient routes (Real-Time Traffic Control, 2023; Babenko et al., 2023).

Literature Review

Scientific publications by specialists in the management of transport systems based on artificial intelligence cover various aspects of using intelligent systems, big data analytics, and visualization to optimize decision-making in logistics. In particular, the authors presented a decision-making model developed specifically for logistics (Peťo & Peťo, 2013). They focus on the integration of various decision-making processes to improve the efficiency of logistics management, consider the factors influencing logistics decisions, and offer a systematic approach to optimize these processes. The main contribution of this paper is providing a structured model that can be implemented to improve decision-making outcomes in logistics operations, especially in complex supply chains. However, the research lacks empirical verification and remains largely theoretical.

Logistics services expert Akhtar (2023) conducts a thorough literature review on logistics outsourcing. The paper systematically examines factors influencing outsourcing decisions, such as cost, service quality, and strategic importance. Research gaps are also identified, such as the need for a better understanding of outsourcing risk management. The strength of the study lies in its comprehensive analysis and clear identification of gaps, which lays the foundation for future research. However, the focus on theoretical conclusions without empirical evidence limits its practical application.

The paper by Zoubek and Šimon (2021) explores the role of big data analytics in improving decision-making in smart logistics. The authors use a case study approach to demonstrate how big data can help uncover useful insights, thereby increasing efficiency and responsiveness. A case study provides practical evidence of the impact of analytics on logistics, which is a strength of the paper. However, a limitation of the study is that it covers only one case, and its findings may not be generalizable without additional research.

Govindan et al., (2018) provide a comprehensive review of green supply chain management (GSCM), focusing on definitions, measurement methods, and implications for future research. They also provide an example from the automotive industry that helps illustrate the practical applications of GSCM. The main strength of this review is its systematic categorization of GSCM practices and the identification of gaps that require future research. However, the broad scope of the article sometimes makes it difficult to apply specific insights without a clear application framework.

The authors use a fuzzy multi-criteria decision-making (MCDM) approach for supplier selection in the logistics sector with a focus on sustainability (Jagtap & Gupta, 2020). Using an example from India, they demonstrate how fuzzy MCDM can handle complexity and uncertainty in supplier selection. The strength of this paper is the application of a rigorous decision-making methodology that is well-suited to uncertain situations in logistics. However, the use of only one example limits the broader applicability of their findings.

Some scholars conduct a systematic review to analyze how information technology affects decision-making processes in logistics (Windt & Hulsmann, 2007). Additionally, experts examine various IT systems, such as enterprise resource planning (ERP) systems and decision support systems (DSS), that help in logistics management. The paper's strength lies in identifying both the benefits and challenges of IT implementation, providing a balanced view. However, since the literature review is somewhat dated, recent technological advances, such as artificial intelligence and machine learning, may not be fully covered.

A systematic literature review on smart logistics in the context of digital transformation is provided in the scientific literature, focusing on how digital technologies are changing logistics management (Can Sağlam, 2022). The authors examine the opportunities provided by smart technologies such as automation, the Internet of Things (IoT), and artificial intelligence (AI) (Pylypenko et al., 2023). The paper's strength lies in summarizing recent research, but it lacks empirical data or research that could provide a more realistic view of the implementation of these technologies in real-world settings. It should be noted that, although many studies focus on theoretical aspects, future research should pay more attention to empirical verification and application in real-world settings.

Thus, the main problems related to the visualization of information in logistics systems are the lack of tools for presenting large, complex, and real data, as well as the lack of standardization and user-friendly interfaces. In the case of intelligent decision-making systems, the challenges related to integrating data from disparate sources, ensuring data quality and reliability, and ensuring interpretability and trustworthiness of system outputs for stakeholders with varying levels of technical training. Overcoming these challenges is critical to realizing the full potential of information visualization and intelligent decision-making systems in improving logistics efficiency and decision-making quality.

Methodology

The methodological foundation of the research consists of a combination of general philosophical and specific methods, principles, and approaches, with the primary methodological approaches being systemic, process-oriented, and situational. General scientific methods: systematic approach - for substantiation of the metrics for assessing the effectiveness of advertising campaigns; analysis and synthesis - to determine trends and trends in the development of artificial intelligence; methods of theoretical generalization - to determine the disadvantages and advantages of traditional and alternative methods of evaluating the effectiveness of advertising campaigns using artificial intelligence technologies; terminological analysis - to identify and clarify terms that reveal the essence of evaluating the effectiveness of advertising campaigns in digital advertising services.

Specific research methods: statistical and analytical methods - to evaluate the effectiveness of advertising campaigns in the Google Ads digital service based on the comparative results obtained when using traditional and alternative methods involving artificial intelligence algorithms.

Results

The growth in population, cars, and cities has a profound impact on our lives, and congestion in the transport system is a major consequence of this urbanization and growth. Here are some of how these factors affect us (Predicting perceived risk, 2023):

Congestion of the transport system is a significant problem in many cities around the world, and it poses numerous challenges and negative consequences for individuals, communities, and economies. Here is a deeper look at the problem of traffic congestion:

- Lost Time: One of the most obvious and immediate consequences of traffic congestion is the time lost by road users. Long travel times mean less time for productive activities, leisure, and socializing with family and friends. This can lead to increased stress and reduced quality of life.

- Economic costs: Overloading traffic leads to significant economic costs. These costs include fuel consumption due to inactivity on the road, increased transportation costs for businesses, and reduced overall productivity. Companies may experience delays in supply chains, and the economy may suffer as a result.

- Air pollution: Overcrowded traffic is a major factor in air pollution, as vehicles emit more emissions when they get stuck in the road or move at slow speeds. Pollutants emitted from cars, such as carbon monoxide, nitrogen oxides, and particles, can hurt air quality and human health.

- Health Effects: Prolonged exposure to overload and air pollution can lead to various health problems, including breathing problems, cardiovascular diseases, and an increased risk of cancer. Especially vulnerable children, elderly people, and people with previous health conditions.

- Safety concerns: traffic congestion can increase the likelihood of accidents. When vehicles are closely located to each other, which often occurs when entering traffic jams, there is less room to maneuver, and drivers can become more aggressive. This can lead to higher accident rates and more serious accidents.

- Performance Reduction: Companies often suffer from late employees to work or important appointments due to congestion in the transportation system. Productivity can decrease as employees spend more time on the road and less time at work.

- Infrastructure costs: To cope with the congestion of transport systems, cities often have to invest in roads, expanding roads, building new highways, or improving public transport systems. These projects can be financially difficult and can take years.

- Quality of life: overload can have a profound impact on the overall quality of life in the city. This can lead to frustration, hostility on the roads, and a reduced sense of well-being for residents.

The solution to traffic overflow problems usually involves a combination of strategies, including investing in public transport, implementing barrier pricing, promoting the common use of cars, encouraging cycling and walking, and introducing intelligent transport systems (Karasu, 2023; Savytska et al. 2023, 2024; Computer Vision, 2023; Creating Augmented, 2023). Urban planning, which focuses on mixed land use and building more pedestrian areas, can also help reduce the need for long car journeys. Ultimately, congestion management is a complex problem that requires a comprehensive, multifaceted approach to improving transportation systems and urbanization.

Routing

Usually, to improve the routing situation, we use navigators. Navigators, also known as GPS navigation systems or GPS devices, can be extremely useful in navigating through traffic in cities (Designing Data-Intensive Applications, 2023 Babenko, 2013; Hrabovskyi et al., 2020). Here's how navigators help with traffic:

- Real-time traffic updates: Many modern GPS navigators are equipped with real-time traffic data. They receive information about current traffic conditions, crashes, road closures, and obstacles from various sources, including traffic sensors, GPS signals from other drivers, and traffic control centers. These data are then used to calculate the optimal route for the driver, avoiding areas with high traffic.

- Alternative route suggestions: Navigators provide alternative routes to help drivers avoid traffic jams. When an overload is detected on the scheduled route, the navigator can automatically redirect the driver to a faster or less congested path. This feature is particularly valuable in cities where rapid changes in traffic conditions are possible.

- Estimated arrival time: GPS navigators offer a typical arrival time based on current traffic conditions. These ratings are updated as the driver progresses along the route. Knowing when you arrive at your destination helps in managing time and planning.

- Incident message: Navigators often provide warnings about crashes, road closures, construction zones, and other incidents that may affect the route you choose. These alerts allow drivers to make informed decisions about whether to extend their current route or choose an alternative route.

- Voice navigation: Navigators offer rotary, voice navigation, which means drivers receive voice guidance on when to turn and which tracks to use. This reduces the need for a glance at the device screen, improving safety when navigating through urban traffic.

- Track Help: Many GPS navigators provide track help, helping drivers stay on the right track while navigating difficult junctions and motorway exits. This is especially important in overcrowded urban areas with complex road networks.
- Points of Interest: Navigators often include a database of attractions such as gas stations, restaurants, parking lots, and tourist attractions. This feature allows drivers to easily find services and amenities, reducing the time spent searching while driving.
- Offline Maps: Some GPS navigators allow users to download maps for offline use. This can be useful in areas with poor or no cellular coverage, ensuring that navigation functions continue to operate without an internet connection.
- Settings: Users can often configure GPS navigation settings, such as avoiding roads, motorways, or specific areas prone to traffic congestion. This personalization allows drivers to tailor their navigation experience to their preferences and needs.
- Traffic Analysis: Some advanced GPS devices can analyze traffic patterns and provide suggestions for the best travel times, helping drivers avoid peak hours of overcrowding when possible.

GPS navigators help alleviate urban traffic congestion by providing real-time updates, offering alternative routes, estimating arrival times, and delivering valuable road condition information (Kuznetsov et al., 2029). These features improve navigation efficiency, help drivers avoid congestion, reduce travel time, and contribute to a safer and more comfortable driving experience in urban areas.

Of the features listed, the most relevant for this study are real-time traffic updates and the ability to build alternative routes. This is typically achieved by tracking geolocation data from vehicles, which helps identify traffic load on specific segments of a route. This allows for the calculation of routes based on how many cars pass through a certain stretch of road over a specified period. While this technology functions as intended, a challenge remains in the updating of alternative routes. Events such as accidents or repairs on the road are typically entered manually by drivers or specialized services, which can cause delays in providing optimal routing information. The proposed solution to this problem is the implementation of a system using computer vision that can transmit information about repairs or unforeseen events, resulting in more accurate and timely route updates.

Computer vision

Computer vision is an area of artificial intelligence (AI) and computer science that focuses on allowing computers to interpret and understand visual information from the world, just as humans do with their own eyes. It involves the development of algorithms, models, and methods that allow computers to process, analyze, and extract meaningful representations from images and videos. Computer vision has a wide range of applications, including in the automotive industry, where it is integrated into automotive systems to enhance safety, navigation, and driver assistance functions.

Here's how computer vision integrates into automotive systems:

- Computer Vision is a fundamental component of ADAS, which includes features such as lane departure warning, adaptive cruise control, and blind spot monitoring. Cameras located around the vehicle, shoot real-time video shots of the environment. Computer vision algorithms analyze this data to identify lane markings, other vehicles, pedestrians, and potential hazards. This information is then used to provide alerts to the driver or even help to control the movement of the vehicle.

- Computer Vision systems can identify potential collision risks and launch alerts or stand-alone actions to prevent crashes. For example, if the system detects an imminent collision with a vehicle or a pedestrian, it can automatically apply brakes or direct the vehicle to safety.

- Many modern cars are equipped with parking assistance systems that use computer vision to help drivers pack safely. Cameras provide a view of the area around the vehicle, and the system imposes graphics or instructions on the screen to help the driver position the vehicle within the parking lot.

- Computer Vision can be used to recognize and interpret traffic signs and signals. Cameras in the car control the road by signs such as speed limits, stop signs, and traffic lights. The system can provide the driver with visual or auditory prompts, reminding them of the current traffic rules.

- Computer Vision algorithms can identify pedestrians near a vehicle, even in low light conditions or in view violations. This is very important for pedestrian safety and can be integrated into autonomous emergency braking systems.

- Automotive systems can use computer vision to identify and classify various objects on the road, such as vehicles, cyclists and garbage. This information can help in making driving decisions and avoiding collisions.

- Computer Vision can observe lane markings and provide feedback to the driver when inadvertently departing from the lane. Some systems may even use steering input to automatically keep the car in its lane.

- Adaptive headlights can adjust their sample beam based on vehicle speed, control angle, and road distortion, all can be determined by computer vision analysis.

- Computer Vision can be used to monitor driver behavior, including detecting signs of drowsiness or distraction. If the system detects such behavior, it can provide a notification to keep the driver focused on the road.

Computer Vision is a critical technology integrated into automotive systems to enhance safety, improve driver assistance, and empower more advanced autonomous driving capabilities. By analyzing the visual data from the cameras located around the vehicle, computer vision systems help cars perceive the environment and make informed decisions to ensure safer and more efficient driving (Figure 1).

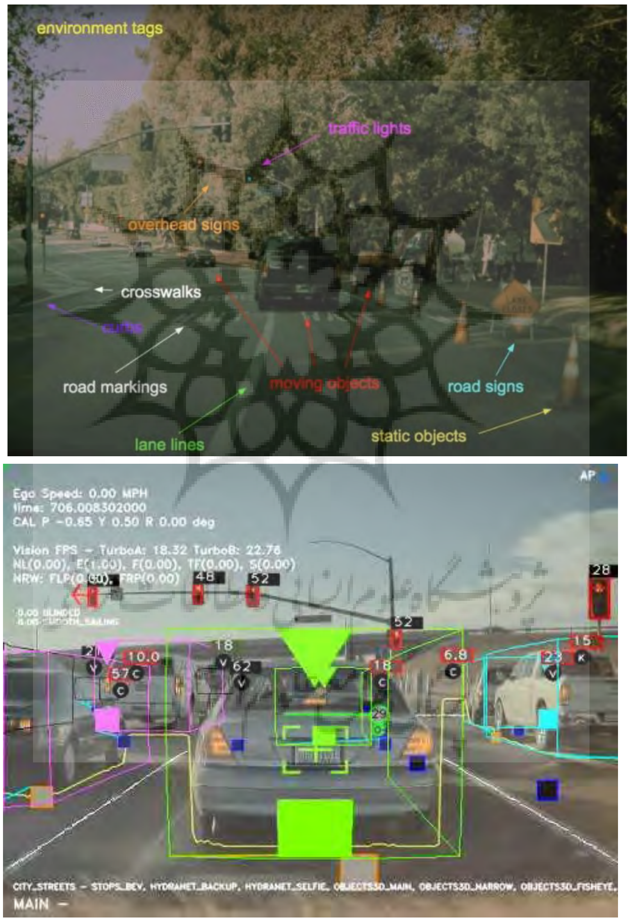

Figure 1. Interpretation of the roadway through the eyes of man, we see some objects, and our brain makes appropriate conclusions considering each of the aspects

An example of how the Computer Vision system can recognize objects. We can find similarities with how our brain processes information about objects transmitted by our eyes and how it does Computer Vision. What interesting things can be used to improve routing through our system? In these two pictures, we can see traffic lights and temporary signs that limit traffic on a given lane, due to the received data on the time of turning on the colors on traffic lights, we can correct routes by searching for the most profitable options, the more cars in different parts of the city will be able to transmit such information the more accurate the forecast will be created on routes, at the expense of road signs, their recognition can be used to avoid certain sections of the route if this lane is the most loaded.

Distributed data processing system

To combine data from different vehicles and analyze it for further conversion into a type of information that will improve the quality of routing decisions, it is necessary to create a system that will provide an opportunity to send, process, and aggregate the result (Nesterenko et al., 2024; Kyrylieva et al., 2023).

Building a system to collect data involving millions or even more cars, handling it with Computer Vision to detect traffic accidents or identify traffic lights, and using this data to predict a route on such a large scale is a difficult task that requires careful planning, scalability, and high-level technology (Kashchena et al., 2024). Here is the general architecture for such a system:

1. Data collection:

• Sensors on board: Equipping vehicles with sensors including cameras, LiDAR, radar, and accelerometers to collect data relating to the environment of the vehicle.

• Data Capture: Developing a robust data acquisition system that can collect data from millions of cars at the same time. Use cloud solutions for scalable data storage.

2. Computer Vision:

• Local Processing: Implement automotive calculations for local data processing and analysis. This reduces the need for constant data transmission.

• Deep learning models: Design and implement deep learning models for computer vision on vehicles capable of detecting various situations, including road accidents.

• Real-time processing: Provide real-time data processing capabilities to detect crashes at the time they occur.

3. Data aggregation:

• Data transmission from the car to cloud environments: Data that require additional analysis or that have been skipped by local processing can be transmitted to the cloud for aggregation and post-processing.

• Data Flow Processing: Use of Real-Time Data Processing Systems such as Apache Kafka or Apache Flink.

4. Deployment using cloud solutions:

• Scalable cloud infrastructure: Deploying scalable cloud infrastructure to handle large amounts of input data using technologies such as AWS, Azure, or Google Cloud.

• Data Storage: Store and manage incoming data efficiently using distributed databases or Data Lakes.

• Data Processing: Developing a robust and distributed data processing system using technologies such as Apache Spark for further analysis and prediction.

5. Integration:

• API: Providing an API for integrating third-party services, such as navigation applications or emergency maintenance services.

6. Security and Privacy:

• Data Protection: Implement strong encryption and security measures for data during pre-

7. Monitoring and maintenance:

• Continuous monitoring: introduction of reliable monitoring to identify systemic problems and bottlenecks of performance.

• Scalability: Designing a system for horizontal scaling, to dynamically scale based on the amount of traffic being transferred to the system.

Discussion

This approach has the potential to significantly reduce congestion, reduce emissions, and improve overall transport efficiency in urban areas (Traffic Management System, 2023; Gontareva et al., 2020). However, the successful implementation of such a system will require overcoming various technical, material and technical problems and confidentiality issues (Cities, 2023). In addition, the computer vision routing model can benefit from further discussion on data security, scalability, and potential impact on driver behavior (Prediction of departure delays, 2023; Cities, 2023; A comprehensive study, 2023).

In general, the issue of building a routing model deals with an important issue and offers a promising solution through the use of computer vision and data processing, but it should consider in more detail the practical implementation and potential consequences of such a system.

The goal of the article is to solve the problem of congestion in cities caused by the excessive number of vehicles, offering a system that uses computer vision technology to collect and process data from vehicles. The main purpose of such a system is to provide more accurate and timely information to drivers, allowing them to make informed decisions about their routes and, ultimately, reduce traffic congestion, improve transport efficiency, and minimize the impact of urban travel on the environment.

Conclusion

The relevance of the idea of development is considered and what impact it can have on users. A model for improving the quality of analysis and improvement of routing is presented, which problems will need to be solved during the implementation of this development and possible integration options with existing systems. The next steps can be to find opportunities for interactions between transport data and to consider the possibilities of processing such data in large volumes.

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Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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