IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed / Refereed journal ⁜ Vol. 11, Issue 11, November 2024

DOI: 10.17148/IARJSET.2024.111112

AI TOWARDS ROAD SAFETY

Pooja S Kiragi, Veeresh Angadi, Venkatadri V, Rakshith B S, Abhishek N Biradar

Dayananda Sagar Academy of Technology and Management, Bangalore, Karnataka

Abstract*:*This paper reviews advancements in Artificial Intelligence (AI) and Machine Learning (ML) for road safety and accident prevention. It explores various techniques for developing intelligent road safety systems, emphasizing driver behavior, vehicle conditions (two-wheelers and four-wheelers), road and bridge integrity, and theft issues using Radio Frequency Identification (RFID). The findings suggest that Machine Learning enables real-time updates to safety systems, fostering a smart and efficient framework. AI enhances these systems by monitoring driver behavior, such as drowsiness detection via camera feeds. The paper also addresses AI's role in assessing road and bridge conditions while noting certain limitations.

Index Terms: Artificial Neural Network (ANN), Rasberry Pi (RPI), Radio Frequency identification (RFID), Global Positioning System (GPS), Intelligent Transportation System (ITS), Optical character recgnization(OCR).

I. INTRODUCTION

The rapid urbanization in India has led to increased traffic congestion, rendering traditional traffic management systems ineffective. This situation has heightened the importance of road safety due to the rising number of fatalities from road accidents. As vehicle numbers surge, it is crucial to develop optimal solutions to ensure the safety of road users and reduce mortality rates.

Advancements in technology have facilitated the creation of various road safety methods globally, leveraging Artificial Intelligence (AI) and Machine Learning (ML) to enhance analytical efficiency. Researchers have identified two primary areas to prevent road crashes: (a) analyzing driver behavior under different conditions and (b) gathering data on driving speed, brake usage, and engine parameters in diverse environ- ments.

The methods developed generally consist of three key components: First, employing Machine Learning models to analyze driver behavior; second, collecting data from multiple sensors and linking them to servers and network devices for processing via the Internet of Things (IoT); and third, creating user-friendly interfaces, such as mobile applications, for easy access.

This paper reviews the application of AI and ML in road safety and smart transportation systems. It discusses the role of these technologies in detecting drowsiness, alcohol con- sumption, speeding, and the absence of safety gear like seat belts and helmets, ultimately aiming to prevent accidents and save lives. Additionally, the paper addresses the limitations of these technologies in enhancing road safety and proposes a system for future research and the development of smart cities, particularly in transportation.

II. TECHNOLOGIES USED [?]

A. Artificial Neural Networks (ANNs):

ANNs can improve road safety by predicting accidents, analyzing traffic patterns, and aiding intelligent transportation systems. Key applications include:

Accident Prediction: Data collection and model training. Traffic Pattern Analysis: Recognizing patterns from data. Driver Behavior Analysis: Assessing risk based on behav-
ioral data.

Road Condition Monitoring: Predicting conditions using sensor data.

Intelligent Transportation Systems (ITS): Implementing adaptive control.

Implementation Steps: Data preparation, model design, training, deployment, and evaluation.

B. Raspberry Pi:

This low-cost microcomputer is ideal for AI applications in road safety due to its portability and compatibility with sensors. Applications include:

Accident Detection: Data collection and machine learning models.

Driver Monitoring: Drowsiness and alcohol detection. Vehicle Monitoring: Speed and safety gear checks.

Traffic Management: Real-time monitoring and congestion detection.

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Implementation Steps: Hardware setup, software develop- ment, and model training.

C. *Radio Frequency Identification (RFID):*

RFID enhances road safety by tracking vehicles and moni- toring traffic conditions. Applications include:
Vehicle Identification: Using RFID tags and readers. Driver Behavior Monitoring: Collecting behavioral data. Traffic Management: Real-time flow and incident detection. Automated Toll Collection: Streamlining toll processes.
Integration with AI: Enables predictive analytics and real- time decision-making.

D. *Global Positioning System (GPS):*

GPS provides accurate location data for vehicles, enhancing road safety through real-time monitoring and analysis. It aids in accident prevention, traffic management, and emergency response.

E. *Optical Character Recognition (OCR):*

OCR automates the extraction of textual information from images and videos, improving road safety through:
Vehicle Identification: Recognizing license plates.
Traffic Sign Recognition: Monitoring compliance with road signs.
Driver Behavior Monitoring: Analyzing driver actions.
By integrating these technologies, road safety can be sig- nificantly enhanced, leading to safer and more efficient transportation systems.

III. LITERATURE SURVEY

With the rapid growth of modernization, there is a havoc rise in traffic, which increases congestion and leads to severe crashes and accidents, putting many lives in danger. Approx- imately 1.35 million people lose their lives every year due to accidents, and around 50 million suffer from severe injuries. With India focusing on building smart cities, this is a major concern for India to find an effective solution. The best way to implement AI and Machine Learning techniques is to create a smart road safety system that will analyze the physical parameters of vehicles and study the drivers' behavior, which will efficiently reduce congestion, reduce the time of travel, and help prevent crashes.
AI and Machine Learning are both the most booming technologies of today. Machine Learning, a branch of artificial intelligence and computer science, focuses on using data and algorithms the way humans learn with accuracy. Machine Learning uses data, various algorithms, and statistical methods to understand, recommend, classify, and detect different situ- ations with high accuracy. Thus, we can use these booming technologies to make a highly efficient and user-friendly road safety system.
For example, as discussed in [6], to tackle the problem of traffic congestion leading to crashes and accidents due to the increase in population during the 2022 World Cup in Qatar, naturalistic driver behavior is utilized to collect and analyze the data for traffic planning to maintain safety. An AI-based solution is implemented, which collects vehicle data like the time of the trip, GPS location, maximum, minimum, and average speed to study the data and predict accidents and road infrastructure development to prevent crashes. The driver's behavior is also considered, including the driver's drowsiness level. Figure 1 from [7] describes the alarming situation in road safety due to driver drowsiness. A framework and a deep learning-based application are implemented to check the drowsiness level of the driver with an accuracy of 82%.
In [8], a cost-effective, novel AI architecture is made with robust computational methods in assessing road safety. This safety system approach to road safety is now adopted worldwide. However, the considerations are made for the medium-to-long term. This work implements the approach for a short-to-medium-term dynamic assessment of road safety. In addition, the use of machine learning in the design of the computational core is showcased by using an application of Hidden Markov Models. The proposed architecture is demon- strated through an application to safety-based route planning

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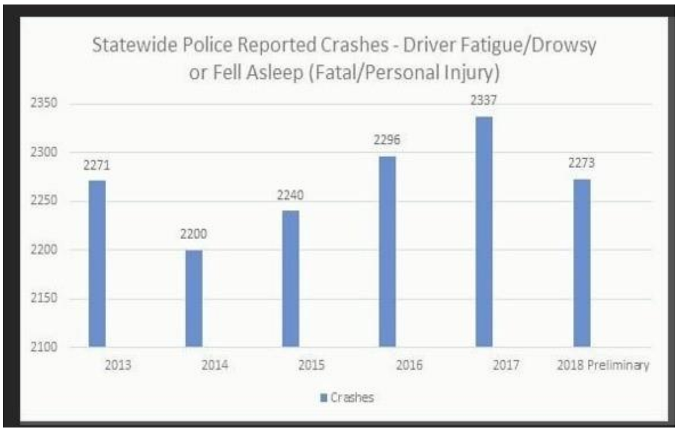

Fig. 1. Accidents due to drowsiness

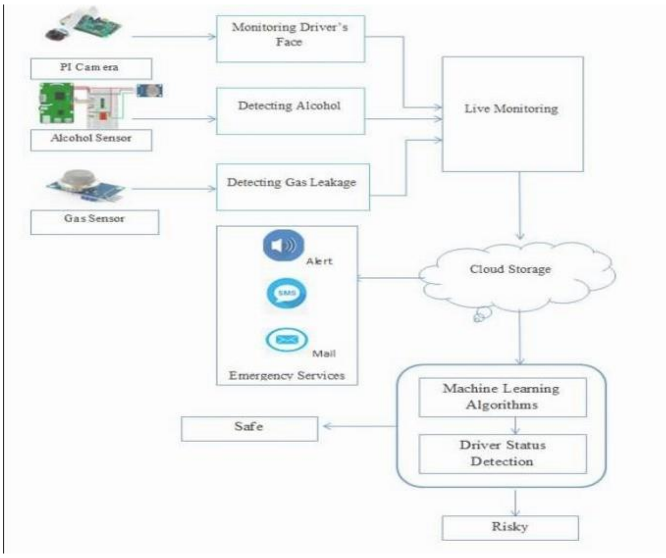

Fig. 2. General architecture of the model

Machine Learning also plays a vital role in predicting acci- dents. Prediction of automotive accident severity is important for an intelligent traffic system. In [9], some classification models like Logistic Regression, Artificial Neural Network, Decision Tree, K-Nearest Neighbors, and Random Forest have been implemented to predict accident severity. A secure com- munication architecture model has been explained to exchange information among the devices, and a web-based alarm system is introduced that can alert the user of any accident. However, these techniques require a wide range of land data as input, reducing to a low resolution and losing detail. So, to solve this problem, a solution as stated in [10] has been proposed to use a high-resolution data framework, and the application of IoT is the deep learning architecture of Convolutional Neural Network (CNN). It is found that high resolution of data provides results with more accuracy.

Several solutions have been presented to solve the problem of tackling traffic congestion [11]. One of these methods is to solve this problem through Artificial Neural Networks (ANN). Modeling Smart Road Traffic Congestion Control using Artificial Back Propagation Neural Networks (MSR2C- ABPNN) is proposed [12] with the help of ANN for road

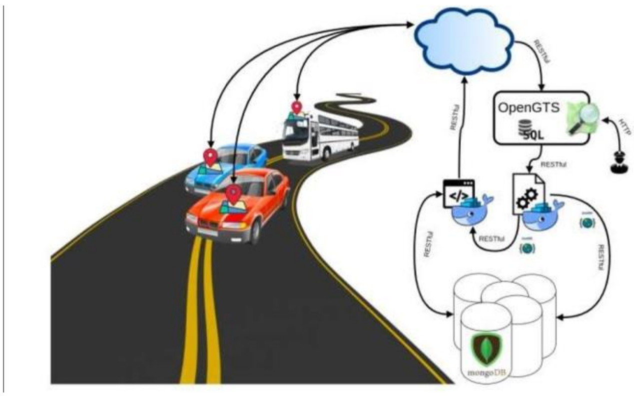

Fig. 3. Cloud system for traffic monitoring and alert notification.

traffic regulation and control. The proposed MSR2C-ABPNN based model predicts the point of congestion using neural networks and backpropagation algorithms. It is further divided into two sub-layers. The first layer, i.e., prediction layer, backpropagation, is used to detect the occupancy. In contrast, the second layer, i.e., the performance layer, evaluates the prediction layer performance in terms of RMSE, Accuracy, and Miss Rate. Table 1 from [13] shows the statistics of law-breakers in two-wheelers and four-wheelers, which is a major reason behind the proposed use of V2V

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communication technologies, Raspberry Pi, various sensors, MEC architecture, etc., for the prevention of two-wheeler accidents. This system detects accidents by vibration sensors and accelerometers. For detection, the GPS and GSM modules locate the accident site and correspondingly inform the person's nearest ones and nearby hospitals through a text message. The system also requires the person riding the bike to have a valid driving license using the already embedded RFID on the driving license. The RFID reader on the bike will have at most ten registered users, hence handling the related issues. The system is efficient in terms of both parameters and performance.

Furthermore, to prevent accidents, an alerting system has been set up as proposed in [15]. The prototype is designed using Raspberry Pi, Pi Camera, and sensors for monitoring driver's eye movements, detecting yawning, detecting toxic gases, and alcohol consumption to prevent

IV. Methodologies for AI in Road Safety

A. Data Collection and Integration

Sources:

Traffic cameras. Vehicle IoT sensors. GPS and telematics.

Weather APIs and historical traffic data.

Methods:

Real-time data streaming using IoT devices. Integration of heterogeneous data using APIs.

Applications: Traffic density monitoring, incident reporting.

B. Computer Vision

Techniques:

Object detection (pedestrians, vehicles). License plate recognition (LPR).

Lane departure warnings

Tools: Deep learning frames TensorFlow, PyTorch, OpenCV. Applications: Detecting traffic violations, obstacle detection.

C. Machine Learning Models

Supervised Learning: For predicting accident probabilities based on past data.

Unsupervised Learning: Identifying new accident-prone zones.

Reinforcement Learning: Optimizing traffic signal timing for safety.

Applications: Risk assessment, congestion management.

D. Predictive Analytics

Techniques:

Regression models to predict accident risks. Time-series analysis for traffic flow predictions.

Applications: Proactive rerouting, safety warnings.

E. Natural Language Processing (NLP)

Techniques:

Analyzing social media or news for real-time incidents. Processing driver feedback or reports.

Applications: Enhanced situational awareness.

F. Edge Computing and IoT

Techniques:

Real-time analytics on edge devices like cameras or in- vehicle systems.

Integrating low-latency communication systems (e.g., 5G).

Applications: Instant alerts, vehicle-to-vehicle (V2V) com- munication.

G. AI-Powered Decision Support

Techniques:

Multi-agent systems for dynamic traffic management. Risk mitigation recommendations for policymakers.

Applications: Smart traffic systems, urban planning.

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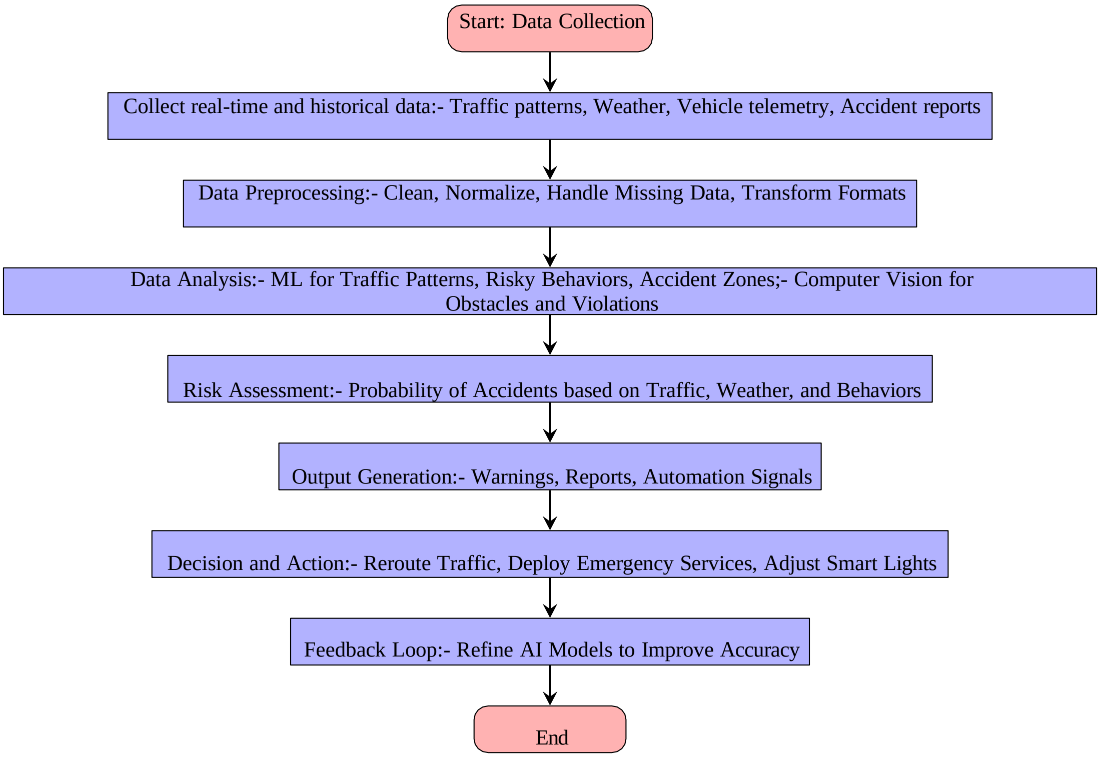
H. ***Autonomous Vehicles***

Techniques:
Path planning algorithms. Sensor fusion for navigation.
Applications: Accident prevention through AI-driven driv- ing.

Flow chart



I. Expected Output

Traffic Prediction The Fig. 4. explains the different approaches to traffic prediction using three input data types: ***Historic Traffic Data***: This data represents past traffic patterns, including volume, speed, and congestion levels.
Real-time Traffic Data: This data provides live updates on current traffic conditions, such as traffic volume, speed, and incidents.
External Data: This data includes factors that can influence traffic, such as weather conditions, social media trends, and events.
These three data types are fed into traffic prediction algorithms. There are three main types of algorithms used: ***Statistical Algorithms***: These algorithms use historical data to identify trends and patterns in traffic behavior.
Machine Learning Algorithms: These algorithms learn from both historical and real-time data to make predictions.
Deep Learning Algorithms: These algorithms are a type of machine learning that use complex neural networks to learn from large datasets and make more accurate predictions.
The traffic prediction algorithms use the input data to produce different outputs:
Forecasting Traffic Flow: Predicting future traffic volume and patterns.
Predicting Jam Occurrence and Evolution: Identifying potential traffic jams and predicting their duration and severity.
Calculating Drivable Speed: Estimating the speed at which vehicles can travel on specific roads under given traffic conditions.

The Fig. 4. illustrates the flow of data from the input types to the algorithms and then to the different outputs. This

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helps to understand how traffic prediction systems use various data sources and algorithms to provide insights into traffic conditions.

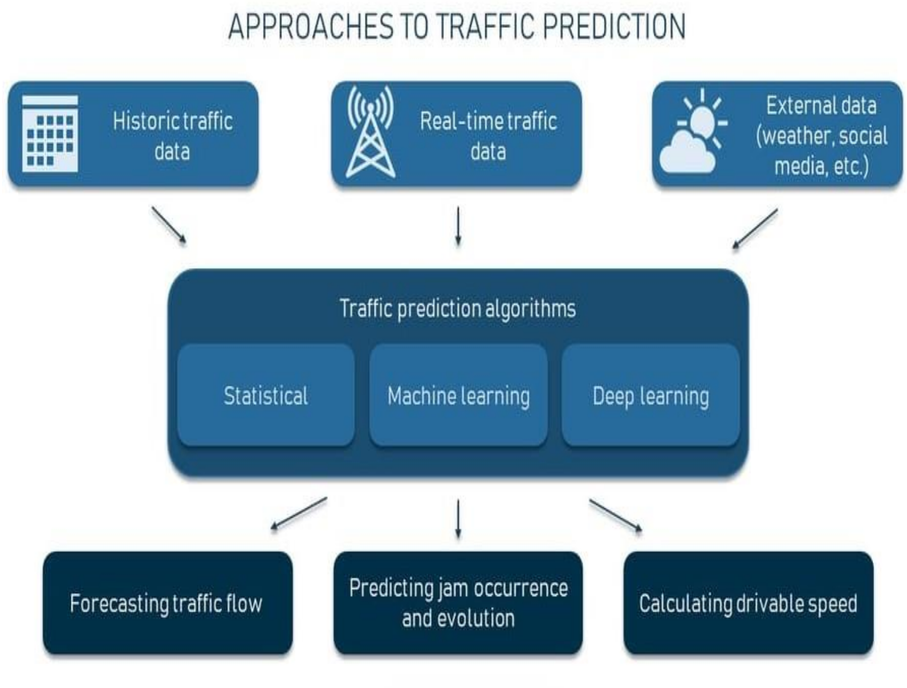

Fig. 4. Cloud system for traffic monitoring and alert notification.

A. Example Problem

Problem: Predicting traffic flow on a highway in Los Angeles from 6am to 9am on a weekday morning.
Input Data:
Historic traffic data: Average traffic volume on the highway at the same time on past weekdays, and how this changes with weather, special events, etc.
Real-time traffic data: Current traffic volume on the highway, and on surrounding roads.
External data: Weather forecast, social media trends indicating potential traffic events (e.g., sporting events, concerts). Prediction Algorithms:
Statistical: Using historical data to calculate the probability of traffic congestion based on past patterns.
Machine learning: Training a model on historical data to predict traffic flow based on specific factors (e.g., day of the week, time, weather, events).
Deep learning: Using complex neural networks to analyze multiple data sources and make predictions. Output:
Forecasting traffic flow: Predicted traffic volume on the highway at different times between 6am and 9am. Example Mathematical Calculation:
Statistical: Assume average traffic volume on this highway between 6am and 9am on Mondays is 1000 vehicles per hour. If the weather forecast predicts rain, which has historically led to a 20 % decrease in traffic volume, the predicted traffic flow for Monday morning would be 800 vehicles per hour (1000 x 0.8).
Machine learning: A machine learning model trained on historical data might predict traffic flow based on a weighted combination of factors such as day of the week, time, weather, and events. For example, the model might assign weights of 0.5 to the day of the week, 0.3 to the time, 0.1 to the weather, and 0.1 to events. If it's a Monday, 7am, raining, and there's no planned event, the model might predict a traffic volume of 900 vehicles per hour (0.5 x 1000 (Monday weight) + 0.3 x 1200 (7am weight) + 0.1 x 800 (rain weight) + 0.1 x 1000 (no event weight)).
Deep learning: A deep learning model would analyze a complex network of factors including historical data

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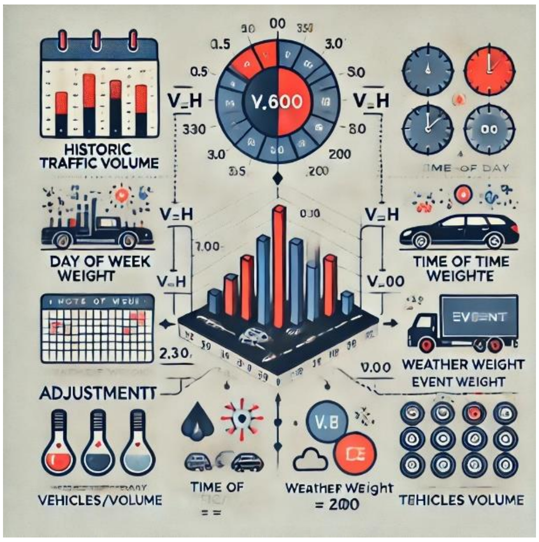

Fig. 5. Formula

*B. **Formula***

Formula for Traffic Prediction Let: (V)=Predicted traffic volume (vehicles per hour)
(Vh)=Average historic traffic volume (vehicles per hour) (Wd)=Weight for the day of the week
(Wt)=Weight for the time of day (Ww)=Weight for weather conditions (We)=Weight for events
(Vd)=Adjusted traffic volume based on the day of the week (Vt)=Adjusted traffic volume based on the time of day (Vw)=Adjusted traffic volume based on weather Conditions (Ve)=Adjusted traffic volume based on events

Step 1: Calculate Adjusted Volumes

Day of the Week Adjustment: [Vd = Vh ×*Wd*] Time of Day Adjustment: [Vt = Vh ×*Wt*] Weather Adjustment: [Vw = Vh ×*Ww*]
Event Adjustment: [Ve = Vh ×*We*]

Step 2: Combine Adjusted Volumes

The final predicted traffic volume can be calculated as: [V = Vd + Vt + Vw + Ve]
Example Calculation Using the example values: (Vh = 1000) (average historic traffic volume) (Wd = 0.5) (weight for Monday)
(Wt = 0.3) (weight for 7am)
(Ww = 0.8) (weight for rain,indicating a 20 %decrease) (We = 1.0) (no event, so weight is 1)

Calculating each component:

(Vd = 1000 ×0.5 = 500)
(Vt = 1000 ×0.3 = 300)
(Vw = 1000 ×0.8 = 800)
(Ve = 1000 ×1.0 = 1000)
Combining these: [V = 500 + 300 + 800 + 1000 = 2600] Thus, the predicted traffic volume (V) would be 2600 vehicles per hour based on the given weights and adjustments.
This formula can be adjusted based on the specific weights and factors relevant to the traffic prediction model being used.

CONCLUSION

The present study focuses on all the various researches made in road safety with the help of AI and Machine Learning. It is seen that, with the help of AI, the safety system can be updated on a real-time basis which can help to create a smart, intelligent, and highly efficient road safety system. AI is applied to enhance the technology further for detecting the driver's behaviour like drowsiness with the help of real-time camera feed or high-resolution images. The true power of AI in ensuring safe driving continues to be unleashed as cars move towards becoming fully autonomous and start interacting with their environment and making decisions on their own. This will prevent drivers from entering hazardous areas, assisting in avoiding collisions, selecting detours, and avoiding traffic congestions. Though research on AI and ML has not yielded much development in Civil Engineering sector, present study definitely gives a major breakthrough in transportation Engineering particularly for road safety measures.

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FUTURE SCOPE

AI is poised to revolutionize road safety in the future. With advancements in machine learning and computer vision, AI can analyze vast amounts of data to predict and prevent accidents. Future scope includes the development of intelligent transportation systems that can detect potential hazards and alert drivers in real-time. AI-powered vehicles will also Future Scope of AI in Road Safety

AI is poised to revolutionize road safety in the future. With advancements in machine learning and computer vision, AI can analyze vast amounts of data to predict and prevent accidents. Future scope includes the development of intelligent transportation systems that can detect potential hazards and alert drivers in real-time. AI-powered vehicles will also be able to make decisions in emergency situations, reducing the risk of accidents.

Key Areas of Focus

Predictive Maintenance: AI can analyze data from sensors and cameras to predict when maintenance is required, reducing the risk of accidents caused by vehicle malfunctions.

Real-time Alert Systems: AI-powered systems can detect potential hazards and alert drivers in real-time, reducing the risk of accidents.

Autonomous Vehicles: AI-powered vehicles will be able to make decisions in emergency situations, reducing the risk of accidents.

Data Analysis: AI can analyze vast amounts of data to identify patterns and trends, helping to improve road safety.

Benefits

Reduced Accidents: AI can help reduce the number of accidents on the road, saving lives and reducing injuries.

Improved Efficiency: AI can help optimize traffic flow, reducing congestion and improving travel times.

Enhanced Safety: AI can help identify potential hazards and alert drivers, reducing the risk of accidents.

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