

AI-DRIVEN ROAD TRAFFIC REGULATION SYSTEM USING YOLOV8 AND LSTM

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ABSTRACT: THE AUTONOMOUS TRAFFIC REGULATION SYSTEM IS AN INTELLIGENT TRAFFIC MANAGEMENT SOLUTION THAT USES ARTIFICIAL INTELLIGENCE (AI), REINFORCEMENT LEARNING (RL), AND COMPUTER VISION TO ENHANCE TRAFFIC SIGNAL CONTROL. ITS MAIN AIM IS TO MODIFY TRAFFIC SIGNALS IN REAL-TIME ACCORDING TO CURRENT TRAFFIC CONDITIONS, WHICH HELPS IN IMPROVING TRAFFIC FLOW AND REDUCING CONGESTION AT INTERSECTIONS. THE SYSTEM COLLECTS REAL-TIME TRAFFIC DATA FROM SURVEILLANCE CAMERAS AND IOT SENSORS INSTALLED AT ROAD JUNCTIONS. IT UTILIZES ADVANCED IMAGE PROCESSING AND DEEP LEARNING ALGORITHMS TO DETECT VEHICLES, ASSESS TRAFFIC DENSITY, TRACK VEHICLE MOVEMENT, AND IDENTIFY AREAS OF CONGESTION FROM VIDEO FOOTAGE. THIS REAL-TIME ANALYSIS OFFERS PRECISE AND CURRENT INFORMATION ABOUT THE STATE OF TRAFFIC. TO MAKE INFORMED DECISIONS, THE SYSTEM USES A REINFORCEMENT LEARNING AGENT THAT IDENTIFIES THE MOST EFFECTIVE WAYS TO TIME TRAFFIC SIGNALS. IT CONTINUOUSLY LEARNS FROM BOTH HISTORICAL AND CURRENT TRAFFIC DATA BY INTERACTING WITH THE TRAFFIC ENVIRONMENT, ENABLING IT TO ADJUST SIGNAL DURATIONS TO MINIMIZE WAITING TIMES, REDUCE TRAFFIC CONGESTION, AND ENHANCE OVERALL TRANSPORTATION EFFICIENCY. THE SYSTEM IS DEVELOPED USING TECHNOLOGIES SUCH AS PYTHON, OPENCV, PYTORCH, IOT SENSORS, AND WEB-BASED MONITORING PLATFORMS. TRAFFIC SIMULATION TOOLS LIKE SUMO (SIMULATION OF URBAN MOBILITY) CAN ALSO BE USED TO TEST AND VALIDATE TRAFFIC OPTIMIZATION STRATEGIES BEFORE THEY ARE APPLIED IN REAL-WORLD ENVIRONMENTS.

KEYWORDS: ARTIFICIAL INTELLIGENCE, COMPUTER VISION, REINFORCEMENT LEARNING, DEEP LEARNING, OPENCV, PYTORCH, IOT SENSORS, TRAFFIC MANAGEMENT, SUMO SIMULATION

I. INTRODUCTION

Traffic congestion has become a major problem in modern cities due to the increasing number of vehicles on the roads. Traditional traffic signals operate on fixed timing schedules, which are not flexible enough to respond to changes in traffic flow. This results in longer waiting times for drivers, higher fuel use, worsened traffic jams, and increased pollution. To address these issues, intelligent and adaptive traffic management systems are becoming increasingly important.

The Autonomous Traffic Regulation System is designed as a smart and efficient solution for managing traffic by using advanced technologies such as Artificial Intelligence (AI), Reinforcement Learning (RL), Computer Vision, and the Internet of Things (IoT). The system continuously monitors traffic conditions through cameras and sensors installed at road intersections and collects real-time traffic data. Using image processing and deep learning techniques, it can recognize vehicles, estimate traffic density, track vehicle movement, and detect congested areas with high accuracy.

Based on this information, a Reinforcement Learning-based decision-making model dynamically adjusts traffic signal timings according to current conditions. Unlike traditional traffic lights that follow fixed schedules, this system learns from traffic patterns and continually improves its signal control strategy. This adaptable approach helps reduce waiting times for vehicles, decrease traffic congestion, and enhance overall transportation efficiency. The project employs technologies such as Python, OpenCV, PyTorch, IoT sensors, and web-based monitoring platforms to develop a scalable and intelligent traffic management framework. Additionally, traffic simulation tools like SUMO (Simulation of Urban

Mobility) can be used to test and validate the effectiveness of the proposed system before it is deployed in real-world environments. By integrating real-time traffic analysis with intelligent decision-making, the Autonomous Traffic Regulation System supports the development of smarter, safer, and more sustainable urban transportation networks.

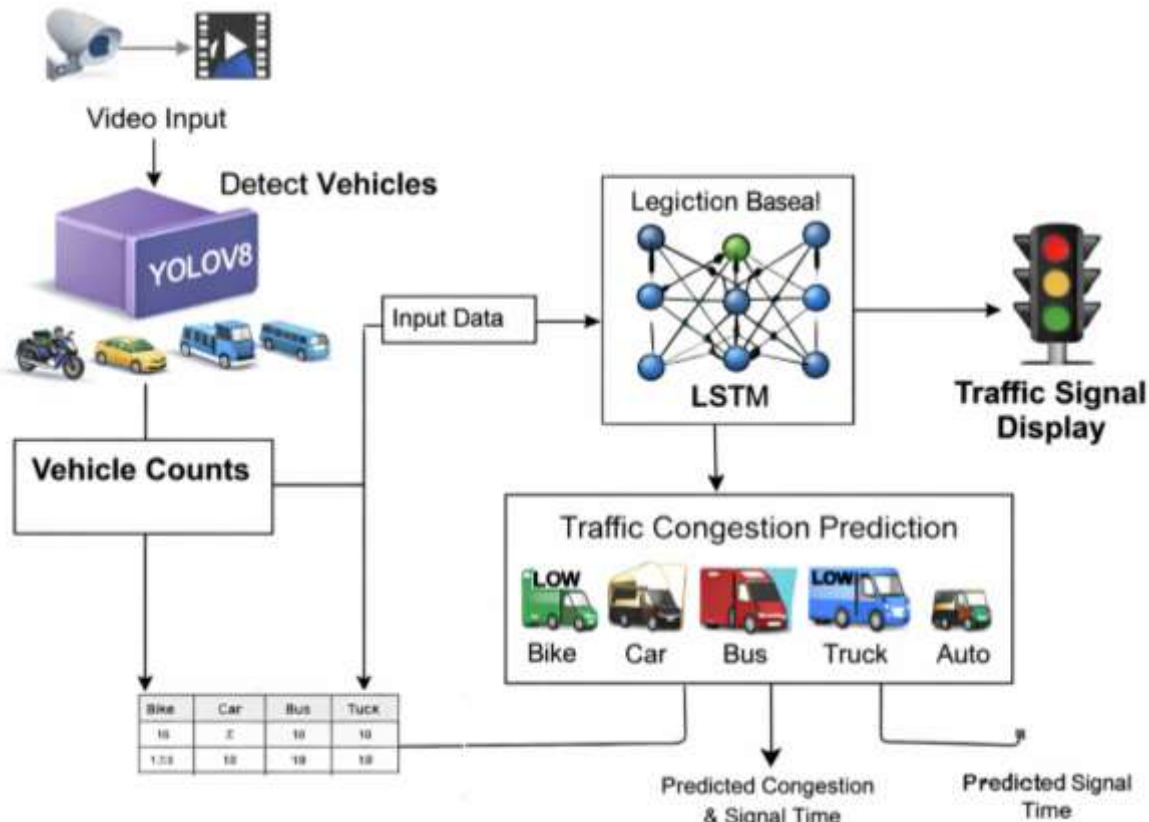
II. PROPOSED SYSTEM

THE PROPOSED AUTONOMOUS TRAFFIC REGULATION SYSTEM IS DESIGNED TO IMPROVE TRAFFIC MANAGEMENT BY UTILIZING ARTIFICIAL INTELLIGENCE, COMPUTER VISION, AND REINFORCEMENT LEARNING TECHNIQUES. UNLIKE CONVENTIONAL TRAFFIC SIGNAL SYSTEMS THAT OPERATE WITH FIXED TIME INTERVALS, THE PROPOSED SYSTEM DYNAMICALLY ADJUSTS SIGNAL TIMINGS BASED ON REAL-TIME TRAFFIC CONDITIONS. TRAFFIC DATA IS CONTINUOUSLY CAPTURED THROUGH SURVEILLANCE CAMERAS INSTALLED AT ROAD INTERSECTIONS. THE CAPTURED VIDEO STREAMS ARE PROCESSED USING IMAGE PROCESSING AND DEEP LEARNING ALGORITHMS TO DETECT, CLASSIFY, AND COUNT VEHICLES PRESENT IN EACH LANE. AFTER VEHICLE DETECTION, THE SYSTEM ANALYZES TRAFFIC DENSITY AND CONGESTION LEVELS ON ALL APPROACHES TO THE INTERSECTION.

THE EXTRACTED INFORMATION IS THEN PROVIDED TO A REINFORCEMENT LEARNING AGENT, WHICH ACTS AS THE DECISION-MAKING COMPONENT OF THE SYSTEM. THE AGENT LEARNS OPTIMAL TRAFFIC SIGNAL STRATEGIES BY OBSERVING TRAFFIC PATTERNS AND RECEIVING FEEDBACK BASED ON TRAFFIC FLOW EFFICIENCY, WAITING TIME, AND QUEUE LENGTH. THROUGH CONTINUOUS LEARNING AND ADAPTATION, THE SYSTEM DETERMINES THE MOST SUITABLE GREEN SIGNAL DURATION FOR EACH LANE.

THE PROPOSED FRAMEWORK ALSO INCORPORATES REAL-TIME MONITORING AND DATA ANALYSIS CAPABILITIES TO ENSURE EFFICIENT TRAFFIC REGULATION UNDER VARYING ROAD CONDITIONS. BY DYNAMICALLY ALLOCATING SIGNAL TIMINGS ACCORDING TO ACTUAL TRAFFIC DEMAND, THE SYSTEM REDUCES UNNECESSARY WAITING TIMES, MINIMIZES CONGESTION, AND IMPROVES OVERALL TRAFFIC MOVEMENT. THIS INTELLIGENT AND ADAPTIVE APPROACH ENHANCES TRANSPORTATION EFFICIENCY, REDUCES FUEL CONSUMPTION CAUSED BY IDLE VEHICLES, AND CONTRIBUTES TO THE DEVELOPMENT OF SMARTER AND MORE SUSTAINABLE URBAN TRAFFIC MANAGEMENT SYSTEMS.

III. SYSTEM ARCHITECTURE



IV. METHODOLOGY

THE RESEARCH METHODOLOGY IS CENTERED ON CREATING AN INTELLIGENT TRAFFIC MANAGEMENT SYSTEM THAT CAN ASSESS TRAFFIC SITUATIONS AND FORECAST CONGESTION LEVELS AS THEY HAPPEN. THIS APPROACH COMBINES COMPUTER VISION, DEEP LEARNING, AND TIME-SERIES FORECASTING TO TRACK VEHICLE MOVEMENT AND IMPROVE TRAFFIC SIGNAL MANAGEMENT. TRAFFIC VIDEO FOOTAGE FROM ROAD INTERSECTIONS GOES THROUGH SEVERAL STEPS, SUCH AS EXTRACTING INDIVIDUAL FRAMES, IDENTIFYING VEHICLES, COUNTING THEM, PREPARING THE DATA, PREDICTING TRAFFIC TRENDS, AND ADJUSTING SIGNAL TIMINGS ACCORDINGLY. THE YOLOV8 MODEL IS USED FOR PRECISE VEHICLE DETECTION, WHILE THE LONG SHORT-TERM MEMORY (LSTM) NETWORK HELPS PREDICT TRAFFIC CONDITIONS BY ANALYZING PAST PATTERNS. A WEB-BASED TOOL HAS ALSO BEEN CREATED TO SHOW REAL-TIME TRAFFIC ANALYSIS AND SUGGEST OPTIMAL SIGNAL TIMINGS.

4.1 DATA COLLECTION AND SYSTEM SETUP

THE PROPOSED TRAFFIC MANAGEMENT SYSTEM BEGINS WITH THE COLLECTION OF TRAFFIC VIDEOS FROM DIFFERENT ROAD LOCATIONS AND INTERSECTIONS. THESE VIDEOS CAPTURE A VARIETY OF VEHICLES, INCLUDING CARS, MOTORCYCLES, BUSES, AND TRUCKS, UNDER DIFFERENT TRAFFIC CONDITIONS AND AT VARIOUS TIMES OF THE DAY. ALONG WITH THE VIDEO DATA, DATE AND TIME DETAILS ARE ALSO RECORDED TO STUDY HOW TRAFFIC PATTERNS CHANGE DURING DIFFERENT HOURS AND DAYS. ONCE THE DATA IS GATHERED, IT IS PROVIDED AS INPUT TO THE SYSTEM.

Time	Date	Dayoftheweek	CarCount	BikeCount	BusCount	TruckCount	Total	Traffic Situation
0 12:00:00 AM	10	Tuesday	31	0	4	4	39	low
1 12:15:00 AM	10	Tuesday	49	0	5	3	57	low
2 12:30:00 AM	10	Tuesday	45	0	3	6	54	low
3 12:45:00 AM	10	Tuesday	51	0	2	5	58	low
4 1:00:00 AM	10	Tuesday	57	6	15	16	94	normal
...	...	...	...	...	...	...	...	...
2971 10:45:00 PM	9	Thursday	16	3	1	36	56	normal
2972 11:00:00 PM	9	Thursday	11	0	1	38	42	normal
2973 11:15:00 PM	9	Thursday	15	4	1	25	45	normal
2974 11:30:00 PM	9	Thursday	16	5	0	27	48	normal
2975 11:45:00 PM	9	Thursday	14	3	1	15	33	normal

THE ENTIRE IMPLEMENTATION IS CARRIED OUT USING PYTHON IN A JUPYTER NOTEBOOK ENVIRONMENT, WHERE THE NECESSARY LIBRARIES FOR IMAGE PROCESSING, DEEP LEARNING, MACHINE LEARNING, AND DATA ANALYSIS ARE INTEGRATED TO SUPPORT THE DEVELOPMENT PROCESS.

4.2 VIDEO PROCESSING AND FRAME EXTRACTION

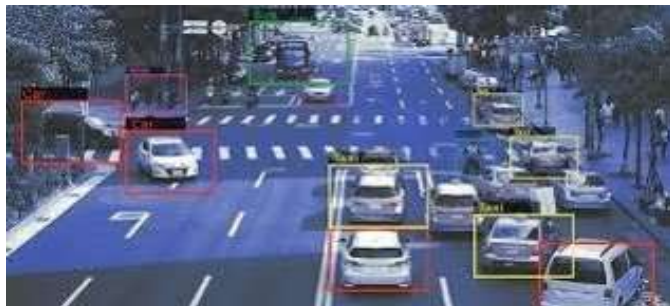
SINCE VIDEOS CONSIST OF A CONTINUOUS SEQUENCE OF IMAGES, EACH INPUT VIDEO IS FIRST BROKEN DOWN INTO INDIVIDUAL FRAMES. CONVERTING VIDEOS INTO FRAMES MAKES IT EASIER TO ANALYZE TRAFFIC CONDITIONS AND DETECT VEHICLES ACCURATELY. EVERY EXTRACTED FRAME ACTS AS A SEPARATE IMAGE THAT CAN BE PROCESSED INDEPENDENTLY.



THIS APPROACH ALLOWS THE SYSTEM TO EXAMINE TRAFFIC MOVEMENT IN DETAIL AND PROVIDES THE VISUAL INFORMATION REQUIRED FOR FURTHER ANALYSIS.

4.3 VEHICLE DETECTION AND TRAFFIC DENSITY ANALYSIS USING YOLOv8

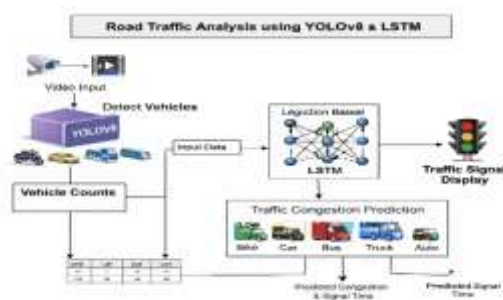
AFTER FRAME EXTRACTION, EACH FRAME IS ANALYZED USING THE YOLOv8 OBJECT DETECTION MODEL. THE MODEL IDENTIFIES DIFFERENT TYPES OF VEHICLES PRESENT IN THE FRAME AND MARKS THEM WITH BOUNDING BOXES.



ONCE THE VEHICLES ARE DETECTED, THE SYSTEM CALCULATES THE NUMBER OF VEHICLES BELONGING TO EACH CATEGORY, SUCH AS CARS, BIKES, BUSES, AND TRUCKS. THESE COUNTS HELP DETERMINE THE TRAFFIC DENSITY ON THE ROAD AND PROVIDE A CLEAR UNDERSTANDING OF THE CURRENT TRAFFIC SITUATION.

4.4 TRAFFIC DATA STORAGE AND PREPROCESSING

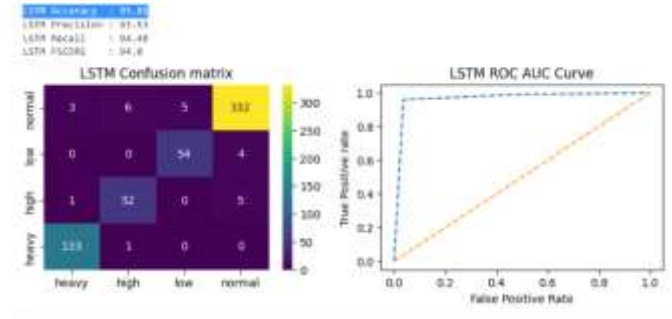
THE VEHICLE COUNT INFORMATION OBTAINED FROM EACH FRAME IS STORED ALONG WITH ITS CORRESPONDING DATE AND TIME DETAILS. ORGANIZING THE DATA IN THIS MANNER HELPS CREATE A STRUCTURED DATASET THAT CAN BE USED FOR TRAFFIC ANALYSIS AND FORECASTING.



BEFORE USING THE DATA FOR PREDICTION, PREPROCESSING STEPS ARE PERFORMED TO REMOVE UNWANTED INFORMATION, HANDLE INCONSISTENCIES, AND ARRANGE THE RECORDS IN A SUITABLE FORMAT. THIS PROCESS IMPROVES DATA QUALITY AND ENSURES THAT THE PREDICTION MODEL RECEIVES RELIABLE INPUT FOR LEARNING TRAFFIC PATTERNS.

4.5 TRAFFIC PREDICTION USING AN LSTM NETWORK

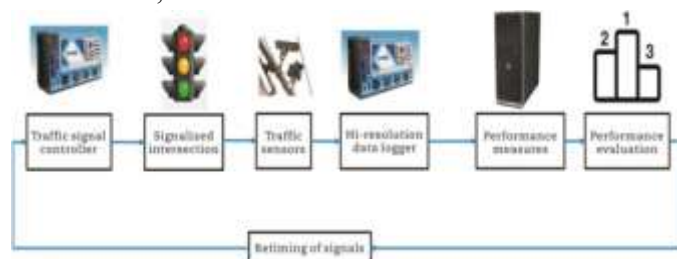
TO FORECAST FUTURE TRAFFIC CONDITIONS, A LONG SHORT-TERM MEMORY (LSTM) NETWORK IS EMPLOYED. LSTM IS PARTICULARLY EFFECTIVE FOR ANALYZING SEQUENTIAL AND TIME-DEPENDENT DATA BECAUSE IT CAN LEARN PATTERNS FROM PREVIOUS OBSERVATIONS OVER EXTENDED PERIODS.



IN THIS STUDY, THE MODEL USES HISTORICAL VEHICLE COUNTS AND TIME-RELATED INFORMATION TO UNDERSTAND HOW TRAFFIC CHANGES THROUGHOUT THE DAY. BY LEARNING THESE TRENDS, THE LSTM MODEL CAN PREDICT UPCOMING TRAFFIC CONDITIONS AND CLASSIFY THEM AS LOW, MODERATE, OR HEAVY TRAFFIC.

4.6 MODEL TRAINING, TESTING, AND PERFORMANCE EVALUATION

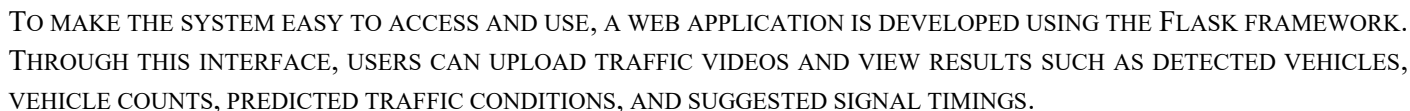
THE PREPARED DATASET IS DIVIDED INTO TRAINING AND TESTING PORTIONS TO ASSESS THE EFFECTIVENESS OF THE PREDICTION MODEL. DURING TRAINING, THE LSTM NETWORK LEARNS THE RELATIONSHIP BETWEEN TRAFFIC VOLUME AND TEMPORAL FEATURES BY CONTINUOUSLY ADJUSTING ITS PARAMETERS. AFTER THE TRAINING PROCESS IS COMPLETED, THE MODEL IS EVALUATED USING UNSEEN TEST DATA TO MEASURE ITS PREDICTION CAPABILITY.



SEVERAL EVALUATION METRICS, INCLUDING ACCURACY, PRECISION, RECALL, AND F1-SCORE, ARE USED TO ASSESS PERFORMANCE. THESE MEASURES HELP DETERMINE HOW EFFECTIVELY THE MODEL CAN PREDICT TRAFFIC CONDITIONS IN REAL-WORLD SCENARIOS.

4.7 ADAPTIVE SIGNAL TIMING AND WEB-BASED IMPLEMENTATION

BASED ON THE PREDICTED TRAFFIC LEVEL, THE SYSTEM AUTOMATICALLY DETERMINES AN APPROPRIATE TRAFFIC SIGNAL DURATION. ROADS WITH HIGHER TRAFFIC DENSITY ARE ALLOCATED LONGER GREEN SIGNAL TIMES, WHILE ROADS WITH LIGHTER TRAFFIC RECEIVE SHORTER DURATIONS. THIS ADAPTIVE APPROACH HELPS IMPROVE TRAFFIC FLOW AND MINIMIZE CONGESTION AT INTERSECTIONS.



THE RESULTS FROM THE PROPOSED AUTONOMOUS TRAFFIC REGULATION SYSTEM DEMONSTRATE THE EFFECTIVENESS OF COMBINING ARTIFICIAL INTELLIGENCE, REINFORCEMENT LEARNING, AND COMPUTER VISION FOR SMART TRAFFIC MANAGEMENT. UNLIKE TRADITIONAL TRAFFIC SIGNAL SYSTEMS THAT FOLLOW FIXED TIMING SCHEDULES, THIS MODEL ADJUSTS SIGNAL DURATIONS IN REAL TIME BASED ON CURRENT TRAFFIC CONDITIONS. THIS FLEXIBILITY HELPS REDUCE UNNECESSARY WAITING TIMES AND IMPROVES OVERALL TRAFFIC FLOW AT INTERSECTIONS. THE VEHICLE DETECTION AND COUNTING MODULE SUCCESSFULLY ANALYZED LIVE TRAFFIC DATA FROM CAMERAS AND SENSORS. BY ESTIMATING TRAFFIC DENSITY ON VARIOUS LANES, THE SYSTEM MADE INFORMED DECISIONS ABOUT SIGNAL ALLOCATION. USING DEEP LEARNING COMPUTER VISION TECHNIQUES IMPROVED THE ACCURACY OF VEHICLE RECOGNITION, EVEN WITH CHANGING TRAFFIC CONDITIONS. THE REINFORCEMENT LEARNING AGENT LEARNED FROM TRAFFIC PATTERNS AND OPTIMIZED SIGNAL TIMINGS BY INTERACTING WITH THE ENVIRONMENT. AS THE NUMBER OF TRAINING EPISODES INCREASED, THE AGENT IMPROVED ITS DECISION-MAKING, LEADING TO LESS CONGESTION AND SHORTER VEHICLE QUEUES.

THIS SHOWS THE POTENTIAL OF MACHINE LEARNING IN TACKLING COMPLEX TRAFFIC MANAGEMENT ISSUES. ANOTHER IMPORTANT BENEFIT OF THE PROPOSED SYSTEM IS ITS SCALABILITY AND ADAPTABILITY. THIS FRAMEWORK CAN BE IMPLEMENTED ACROSS MULTIPLE INTERSECTIONS AND CAN EFFECTIVELY RESPOND TO CHANGING TRAFFIC DEMANDS DURING BUSY AND QUIETER TIMES. ADDITIONALLY, THE SYSTEM REDUCES THE NEED FOR HUMAN INTERVENTION AND ALLOWS FOR AUTOMATED TRAFFIC CONTROL, MAKING IT SUITABLE FOR SMART CITY USES. HOWEVER, SOME CHALLENGES PERSIST. FACTORS LIKE BAD WEATHER, CAMERA BLOCKAGES, SENSOR FAILURES, AND UNEXPECTED TRAFFIC INCIDENTS CAN IMPACT SYSTEM PERFORMANCE. FUTURE IMPROVEMENTS MAY FOCUS ON ADDING VEHICLE-TO-INFRASTRUCTURE (V2I) COMMUNICATION, PREDICTIVE TRAFFIC ANALYSIS, AND EMERGENCY VEHICLE PRIORITIZATION TO BOOST EFFICIENCY AND RELIABILITY. IN SUMMARY, THE PROPOSED AUTONOMOUS TRAFFIC

REGULATION SYSTEM SHOWS THAT SMART TRAFFIC SIGNAL CONTROL CAN GREATLY IMPROVE ROAD TRANSPORTATION EFFICIENCY, LESSEN CONGESTION, AND ENHANCE URBAN MOBILITY.

VI.CONCLUSION

This study presents the autonomous traffic regulation system, which provides a solution to modern traffic issues by combining artificial intelligence, reinforcement learning, and computer vision. The system continuously monitors real-time traffic conditions, detects congestion, and automatically adjusts signal timing to optimize traffic flow. The results show that traffic signals that respond to current conditions significantly boost system performance, decrease average waiting times, and effectively reduce traffic jams compared to traditional systems that rely on fixed schedules.

The system's capability to adjust to changing traffic patterns, made possible by its ongoing learning process, enables it to operate efficiently in constantly evolving environments. The autonomous traffic regulation system makes use of both computer vision and reinforcement learning technologies. The combination of these two allows the system to track and identify vehicles, which, in turn, helps it improve its effectiveness over time. Due to these characteristics, the autonomous traffic regulation system is a solution for smart city settings. This system represents a meaningful progress in the development of intelligent transportation systems in urban areas. With future enhancements such as real-time traffic prediction, vehicle communication, and prioritization of emergency services, the system can reach even higher levels of performance and achieve safe, intelligent urban transportation.

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