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Dynamic Traffic Light Management System using AI and ML

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Abstract*— In an era marked by the expansion of urbanization and increasing vehicular congestion, the demand for effective traffic management is paramount. This study introduces a pioneering Adaptive Dynamic Traffic Light Management System (DILMS) that integrates Artificial Intelligence (AI), Machine Learning (ML), and image processing. The suggested system monitors different lanes using real time data analysis via cameras vehicle identification and counting are accomplished using image analysis with the resulting counts relayed to the main processing unit the program evaluates waiting periods for specific lanes depending on vehicle numbers and then adjusts signal lights. This innovative approach significantly reduces average waiting times, improves traffic clearance efficiency, and contributes to a decrease in CO2 emissions. The system positions itself as a cutting-edge traffic management solution, leveraging the capabilities of AI and ML algorithms.

Keywords: Adaptive traffic management system, Image processing, Machine Learning (ML), Open CV, Average waiting time, Artificial Intelligence (AI), Real-time Data Analysis.

I. INTRODUCTION

The burgeoning urbanization and the ever-increasing number of vehicles on our roads have accentuated the need for innovative and dynamic traffic management systems. Traffic congestion, increased travel times, and environmental concerns have prompted the development of advanced solutions to optimize traffic control and enhance urban mobility. In this context, this research paper presents a comprehensive investigation into the creation and implementation of a Dynamic Traffic Light Management System (DTLMS) empowered by the capabilities of Artificial Intelligence (AI) and Machine Learning (ML). The conventional systems which are used to manage traffic in India are Manual Controlling, Automatic Controlling and Electronic Sensors. In the urban theater of traffic management, the manual controlling system unfolds as a bespoke performance of human finesse. Here, the traffic police don the mantle of conductors, wielding signboards, signal lights, and their own commanding presence to choreograph the intricate ballet of vehicles. With each gesture and whistle, they navigate the flux of the city streets with an elegance that transcends mere regulation, infusing order into the chaos with a touch uniquely their own. In the realm of automated control systems, picture a novel scenario where the automatic traffic light defies convention. No longer tethered to a static timer value, it embraces a dynamic numerical input, orchestrating a ballet of lights that intuitively ebb and flow. Simultaneously, an avant-garde electronic sensor strategy comes to life with strategically placed loop detectors or proximity sensors on the road. This sensor, akin to a data virtuoso, captures real-time insights into road traffic dynamics, influencing the control of traffic signals with finesse and adaptability. The varied patterns of traffic density throughout the day pose an enormous challenge to the current traffic control system in Indian cities. Even in little traffic, this causes vehicles to have to wait for extended periods of time. The problem of fixed timings for light switches is made worse by the manual traffic control system. India's economy is growing at a quick pace, and this is causing a rise in private and freight cars, which is aggravating traffic congestion in in major cities like Delhi, Mumbai, Bangalore, and Kolkata. Compared to their counterparts, commuters in these cities spend an additional fifteen hours a day on average. The predicted peak-hour congestion rate is 149%, which is much higher than the 67% average for Asia. For any individual traversing the bustling streets of India, regardless of their generational identity, navigating the urban landscape poses a formidable challenge—one that most would prefer to avoid. As traffic converges at the fringes of roads or intersects along the bustling streets, the onset of severe traffic congestion becomes inevitable. Vehicles grind to a halt, transforming the thoroughfare into a stagnant tableau, commonly recognized as a traffic jam or colloquially referred to as a traffic snarl-up. The resulting gridlock induces frustration among drivers, often culminating in aggressive maneuvers as they grapple with the conundrum of congested Indian streets.The average waiting time is one of the most crucial measure for tracking traffic congestion according to INRIX 2015 the average time lost in traffic was 101 hours in London commute zone UK and 81 hours in Los Angeles ca in the united states 3-dubey Yayasan Pelangi 2005 study projected that the annual economic losses due by traffic congestion in Jakarta could amount to as much as Rp 128 trillion based on lost productivity fuel costs and medical bills. Number of cars passing through a point in time or a stream is typically used to measure traffic congestion. Some common traffic problems include excessive traffic leading to poor street conditions; excessively congested urban streets from heavily trafficked private vehicles deteriorate the streets' natural characteristics and cause on-going traffic problems. The severity of traffic problems often leads to other health-damaging problems In tackling the intricate issues akin to air and sound pollution on Indian streets, we introduce a pioneering solution — an adaptive traffic control system. This dynamic approach responds to diverse factors such as time, weather, and road conditions, ensuring a balanced dispersal of traffic congestion across the area. Our distinctive strategy not only addresses the challenges of urban navigation but also introduces a novel and effective paradigm for managing the complexities of traffic in Indian cityscapes addressing the challenge of traffic congestion involves considering pollution particularly in urban areas with a high density of vehicles these regions experience increased levels of air and noise pollution due to frequent acceleration and braking in traffic leading to higher fuel consumption and pollutant emissions. CO_2 a significant by-product of vehicular emissions raises environmental concerns according to data from the World Bank data centres. India's co2 emissions per capita were recorded at 166 metric tons. To address this issue more effectively the focus should be on enhancing traffic management systems while toll-based control systems and infrastructure expansions are available alternatives. They are often impractical; a more feasible solution is the development of an adaptive traffic management system capable of adjusting signal timings based on varying traffic density. This project concentrates on three key elements namely- vehicle detection lane, specific vehicle counting and signal time adjustment based on traffic density through the use of real-time data. Pioneering an adaptive traffic management system, we strategically aim to minimize disruptions and halt occurrences at intersections, offering a financially savvy approach to truncate travel durations and amplify commuting velocities within urban transit networks. Our ultimate aspiration is to truncate average waiting periods, consequently curtailing CO_2 emissions at traffic intersections and fostering a substantial reduction in pollution levels, paving the way for a greener and more efficient urban environment.

The significance of this study lies in its potential to revolutionize urban transportation management. The DTLMS promises to address the challenges of traffic congestion, minimize commute times, and enhance road safety. By employing real-time data analysis and predictive algorithms, the system is designed to make intelligent, data-driven decisions, optimizing traffic light control in real-time, and improving urban mobility.

II. LITERATURE REVIEW

1. Navigating through challenges of city traffic particularly in emergencies demands innovative solutions enter the pioneering work unveiled in the 2013 research paper "Adaptive Traffic management for Secure and Efficient Emergency Services in Smart Cities" by Irina Tal ,Mazeiar Salehie, Pooyan Jamshidi and Soufiene, Djahel.

This groundbreaking study introduces a paradigm shift by harmonizing IOT and machine learning to optimize traffic dynamics for emergency vehicle passage. With an array of IOT devices like cameras and controllers, the system orchestrates a real-time symphony of the urban traffic data. What sets this initiative apart is its ingenious use of machine learning algorithms, which decode the traffic patterns with surgical precision, identifying bottlenecks and irregularities. When traffic snarls arise, the system springs into action, dispatching timely alerts to emergency responders and relevant authorities alike. This proactive communication streamlines rerouting procedures for emergency vehicles and facilitates swift synchronized responses from emergency service providers. What truly distinguishes this endeavor is its fusion of IOT and machine learning technologies fashioning a dynamic traffic management system that evolves with the cityscape unlike static rule-bound systems. This adaptive approach ensures agility and responsiveness tailored to the dynamic pulse of urban life in essence adaptive traffic management for secure and efficient emergency services in smart cities represents a bold leap forward in urban traffic management by harnessing cutting-edge technologies. It not only enhances emergency response efficacy but also lays the foundation for smarter safer cities of tomorrow.

2. The research on "Smart Traffic Optimization Using Image Processing" conducted by Deepanshu Suneja, Yogeshwar Mutneja, Praneet Singh , Pranav Maheshwari, and in 2015.

It presents a novel approach to traffic optimization using advanced image processing techniques. Their innovative strategy delves into dissecting the intricate patterns of traffic dynamics, ingeniously blending edge detection techniques with the sophisticated capabilities of Oriented FAST and Rotated BRIEF (ORB) algorithms across a sequence of captured images. This involves converting RGB images to gray scale followed by meticulous edge detection and binary transformation by empowering the system to recognize complex traffic patterns and address challenges related to edge detection. This research introduces Otsu's multiple thresholding technique to improve detection accuracy across varied pixel areas. This is achieved by utilizing distance calculation and road width assessment to precisely estimate the covered traffic area additionally. The integration of the orb algorithm enables the extraction of feature points effectively distinguishing dynamic vehicles from static objects with exceptional precision through the strategic use

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of brute force comparison for feature matching. The system efficiently alleviates traffic congestion, optimizing traffic flow and potentially resulting in savings in fuel and time costs. This innovative approach demonstrates its potential to transform contemporary traffic management practices.

3. Revolutionizing traffic management, the "Smart Traffic Management System Using Internet of Things" integrates both centralized and decentralized approaches to optimize traffic flow and enhance road safety. Developed by, Ali Sufian, Mehak Tanveer Saima Pervaiz, and Sabeen Javaid, this innovative system operates across three distinct layers.

In the realm of Data Acquisition and Collection, a mosaic of sensory ingenuity unfurls its vibrant hues. Here, amidst the digital landscape, CCTV sentinels stand sentinel, flanked by the whispers of ultrasonic sensors and the silent whispers of RFIDs. Yet, it is the unconventional emissaries—the smoke and flame sensors—that imbue this tableau with an otherworldly essence. Together, they choreograph a ballet of data, each note resonating in perfect harmony to unveil the secrets of the world around us. Advanced algorithms such as Blob detection are employed to filter out noise and ensure precise data collection.Shifting to the Data Processing and Decision-making layer, the system dynamically allocates time to each lane based on traffic density, ensuring efficient traffic flow. Notably, it prioritizes emergency vehicles, swiftly adjusting traffic signals to facilitate their passage through intersections.Within the Application and Actuation layer, predictive algorithms like Regression Tree are utilized to calculate rush intervals and update centralized servers with pertinent data for future road planning. Additionally, seamless integration with mobile applications enables prompt alerts to relevant authorities in case of emergencies such as fires or smoke detection.

This sophisticated system heralds a new era in traffic management, leveraging IoT technology to create safer and more efficient roadways.

4. In a groundbreaking approach to traffic monitoring, a research paper titled "Revolutionizing Traffic Monitoring: A Progressive Strategy for Enhancing Indian Road Systems Using IoT," authored by Jasmine Jha and Karan A. Shah and presented at the IJARIIE conference in 2016, introduces innovative methodologies aimed at reshaping the current traffic management paradigm.

The project meticulously unfolds with a focus on addressing the intricate challenges inherent in Indian road networks. The implementation strategy commences by strategically deploying ultrasonic sensors across lanes, meticulously categorized into three priority tiers: high, medium, and low. This meticulous arrangement optimizes data acquisition, with high-priority sensors given precedence over medium and low ones. Consequently, the amassed data, including traffic density metrics and average waiting durations, is seamlessly relayed to the central system for comprehensive analysis. A pivotal aspect of the project involves crafting a prototype model to facilitate exhaustive comparative assessments between the prevailing traffic management system and the proposed IoT-infused solution. Through rigorous testing and evaluation, the IoT-driven system showcases notable enhancements in mitigating waiting times, thereby enhancing overall traffic flow dynamics. By synergizing state-of-the-art sensor technologies with advanced data analytics, this initiative marks a significant leap forward in modernizing traffic monitoring systems, specifically tailored to address the nuanced challenges posed by Indian road infrastructures.

5. Delving into the frontier of Real-Time Multiple Source Video Streaming via Wireless 5.8 GHz, a pioneering initiative led by V.M. Baskaran, S.K. Tiong, and M.Z. Jamaludin from the esteemed Department of Electrical and Electronics Engineering at University Tenaga Nasional, Malaysia, unveils a groundbreaking approach to traffic management. This innovative Intelligent Traffic Management System, fortified by the application of artificial intelligence, heralds a quantum leap in the domain, revolutionizing traffic flow control and congestion alleviation at bustling road intersections. At the heart of this technological marvel lies a sophisticated interplay of sensors and algorithms. Cameras stationed strategically capture snapshots of traffic dynamics, which undergo a meticulous transformation through advanced image processing techniques. These transformed insights, distilled into simple text applications, serve as the lifeblood of the Expert Supervisory System (ESS), a hybrid bastion of Fuzzy Logic and Neural Networks, orchestrating the symphony of traffic management strategies.Yet, the ingenuity does not cease there. These insights transcend mere junctions, cascading into subsequent traffic intersections, enriching the ESS with a plethora of secondary data inputs. Simultaneously, the vigilant cameras, not content with passive observation, relay dynamic motion images to a centralized control hub, empowering real-time surveillance and manual intervention options.However, such seamless coordination necessitates robust communication infrastructure. Thus, the quest for the optimal outdoor wireless uplink ensues, a journey fueled by tireless exploration and meticulous analysis. In this pursuit, each challenge is met with resolve, each obstacle an opportunity to innovate, ensuring the seamless transmission of critical visuals to the remote command center. In this realm where innovation knows no bounds, where technology converges with necessity, the quest for excellence propels forward, propelling humanity towards a future where traffic management is not just a challenge, but a triumph of ingenuity and collaboration.

6. Entitled "Charting Tomorrow's Highways: AI-Driven Traffic Revolution," the collaborative research led by

Kaige Wen, Shiru Qu, and Yumei blazes a trail in freeway network management.

With a sharp focus on Reinforcement Learning (RL), an avant-garde AI technique, the study unveils its transformative prowess in reshaping traffic control paradigms. Pioneering cutting-edge distributed RL methodologies, the research enables rapid policy adaptation for traffic managers and delivers tailored route optimization for drivers. This groundbreaking approach heralds an era of unparalleled adaptability and efficiency, promising to redefine transportation networks and alleviate congestion on freeways with unprecedented ingenuity..

7. Pioneering Precision: Rethinking Vehicle Monitoring Through SIFT Algorithm Fusion.Unveiled at the prestigious IJCAT conference in 2014, the paper "Pioneering Precision: Rethinking Vehicle Monitoring Through SIFT Algorithm Fusion" by Megha C. Narhe and Dr. M. S. Nagmode heralds a revolutionary stride in the realm of vehicle monitoring systems.

At its nucleus, this trailblazing methodology unveils a meticulously orchestrated symphony of technological innovation. Commencing with the dissection of the video clip into a mosaic of individual frames, the groundwork for an intricate analysis is meticulously laid. Building upon this foundation, a sophisticated dance of background subtraction ensues, seamlessly extricating foreground entities, particularly vehicles, from the static backdrop, thereby setting the stage for subsequent refinement.This refinement transpires through segmentation, a pivotal juncture where the system discerns and delineates distinct objects within each frame, with a laser focus on vehicles. This surgical precision in segmentation serves as the crucible for the pièce de résistance: feature extraction. Here, the system harnesses the formidable power of the Scale Invariant Feature Transform (SIFT) algorithm, embarking on a voyage to distill the quintessence of each vehicle encapsulated within the frames.SIFT, revered for its prowess in discerning and extracting features impervious to the caprices of scaling, rotation, viewpoint, or translation, emerges as the veritable lynchpin, ensuring an unparalleled degree of accuracy and reliability in subsequent operations.

The extracted features undergo a ballet of classification, choreographed through an intricate interplay of feature matching mechanisms, all powered by the SIFT algorithm. Each vehicle undergoes meticulous scrutiny, its unique characteristics unraveled, and meticulously assigned to predefined classes with unprecedented precision.

Finally, the crescendo unfolds: vehicle counting. With meticulous finesse, the system tallies the presence of vehicles within the video feed, each count an ode to the triumph of the intricate matching process. Through this culmination, an accurate and reliable census of vehicles traversing the monitored terrain is attained, empowering stakeholders with actionable insights.Central to the system's prowess is the seamless fusion of the SIFT algorithm, heralding a new epoch of precision and reliability in vehicle monitoring. Its adeptness in discerning invariant features amidst a cacophony of transformations ensures resilience and accuracy, even amidst the most formidable real-world challenges.By presenting a comprehensive and meticulously crafted methodology encompassing video processing, feature extraction, classification, and counting, the proposed system stands as a harbinger of innovation. It signifies a promising vista in the domain of transportation and surveillance, emblematic of the relentless pursuit of excellence through avant-garde techniques and unwavering commitment to surmounting enduring challenges.

8. In the hallowed halls of the IEEE Conference (2011) on Sustainable Utilization and Development in Engineering and Technology, Anil Kumar Yerrapragada, Sai Sasank Annasamudram and Prithvinath Manikonda unveiled an unparalleled marvel: the "Intelligent Traffic Management System." This visionary creation, fueled by RFID innovation, redefines traffic control, seamlessly tracking vehicles, optimizing flow, and foreseeing congestion. It stands not just as a solution, but as a beacon of ingenuity guiding us towards a future of fluid urban mobility. This innovative system not only furnishes invaluable real-time traffic data but also holds the potential to significantly mitigate travel times for commuters. Moreover, its utility extends to various other applications such as vehicle tracking for law enforcement purposes like identifying traffic violators, locating stolen vehicles, facilitating toll collection, and managing vehicle taxes, all made possible through the integration of RFID technology.

Crafted with meticulous ingenuity, this system marries a passive tag, a microcontroller, an RFID reader, a GPRS module, and a formidable server housing a sophisticated database system. Complemented by an intuitive user interface, its design transcends convention, seamlessly capturing and processing critical traffic data with finesse and precision. Leveraging RFID technology, it seamlessly gathers pertinent data and computes the average velocity of vehicles traversing each thoroughfare within a given urban landscape.

By leveraging RFID technology, this system adeptly collates essential traffic metrics, enabling the calculation of average vehicle speeds across different road segments within a city. This comprehensive dataset not only empowers traffic authorities to make informed decisions but also offers commuters the potential to optimize their travel routes, thereby fostering a more efficient and streamlined transportation network. Furthermore, the versatility of RFID technology extends beyond traffic management, facilitating diverse applications such as vehicle tracking for law enforcement, toll collection, and vehicle taxation enforcement.

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III. METHODOLOGY

3.1. Working

Introducing an adaptive model that harmonizes with the dynamic density of vehicles at intersections, our innovation transcends traditional traffic control paradigms. This model intricately adjusts its time intervals in response to the ever-shifting tapestry of traffic conditions, seeking to minimize both average waiting time and overall congestion.

Within this ground breaking system, priority allocation is a dynamic process, responsive to the real-time situation. Comprising three pivotal components, each meticulously designed, the system functions as a fluid orchestration, reshaping the conventional hierarchy of traffic management. Our unique approach not only heralds a new era of responsive traffic control but also places an emphasis on situational awareness, aiming to curate a seamless and efficient flow within the urban landscape.

- ***3.1.1. Detection of vehicles.***

Harnessing the eyes of camera sensors strategically positioned in cardinal directions like - North, South, East and West. Our system embarks on a journey of real-time traffic perception. These cameras serving as vigilant sentinels, communicate seamlessly with a Raspberry Pi via USB ports, forming a nexus of data acquisition and processing. Within this innovative framework, a continuous live stream of traffic unfolds, where the intricate dance of vehicles is meticulously measured to gauge the density on roadways. The pivot role of image processing comes to the forefront, with python serving as the language of choice to craft the intelligent algorithms that discern and detects vehicles in this dynamic visual landscape. This fusion of hardware synergy, real-time data processing, and coding finesse not only marks a technological marvel but also propels us into an era where the language of traffic analysis is eloquently spoken through the lenses of sophisticated camera sensors and the precision of Python-powered image processing.

- ***3.1.2. Counting how many cars there are***

We experimented with four lanes in this adaptive traffic control system, using four video sensors for the four distinct lanes. The number of vehicles was counted using these video sensors in each of the four lanes. This guarantees a strategy to lower the mean waiting time. Additionally, issue has been addressed such that logic operates based on the priority we have assigned when the same numbers of vehicles are in many lanes. Innovatively, our system deploys an algorithm designed to intricately juxtapose traffic density data across multiple lanes within a bustling traffic intersection, fostering a nuanced comparison that unveils the dynamic intricacies of vehicular flow.

- ***3.1.3. Determine the waiting period***

The number of vehicles is tallied as part of the waiting time computation and the average waiting time for the traffic light is then calculated after that a signal is sent to the controller allowing traffic to go smoothly in the intended direction for the predetermined amount of time.

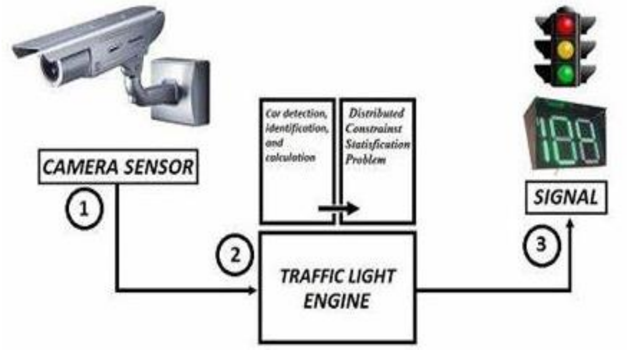

Figure 1. Architecture Diagram

3.2. Algorithm

❖ Algorithm which is used for implementing the Dynamic Traffic Light Management System is:

Traffic Control Optimization Algorithm:

3.2.1 Main Algorithm:

1. Continuously monitor traffic directions.
2. Identify the direction with the highest traffic count (TRAFFIC_COUNT = Find-MAX-Dir).
3. If TRAFFIC_COUNT is non-zero, calculate the optimal signal duration using TIME-CAL-ALGORITHM.
4. Transmit the calculated time to a microcontroller for activating the traffic signal in the identified direction.

3.2.2 Dynamic Time Calculation Protocol:

1. Establishing the length parameter as LENGTH, calculate len = TRAFFIC_COUNT/LENGTH.
2. Dynamically compute TIME as 15 + len.
3. Validation: a. If (TIME ≤ 90 seconds), the protocol returns TIME. b. If not, set TIME to a maximum of 90 seconds and return TIME.

3.2.3 Intelligent Directional Prioritization Strategy:

1. Define directional coordinates as Dir = {0, 1, 2, 3}, initializing priority for each direction to 0.
2. Employ advanced video processing for each direction to ascertain lane counts.
3. Determine the direction (Selected_Dir) with the highest count (MAX(lane0, lane1, lane2, lane3)).
4. Prioritization Assessment: a. If (Priority[Dir] = -10), designate Selected_Dir as Dir. b. Otherwise, proceed to the next step.
5. Check: a. If (Priority[Selected_Dir] < 0), proceed to the next step. b. Otherwise, select the direction (Max_Traffic) with the highest count among the remaining three.

6. Dynamic Priority Adjustment: a. For each direction:
- If (Selected_Dir = Direction), increment Priority[Dir] by 5.
- Else, decrement Priority[Dir] by 5.
7. Conclude the strategy by returning the count of the Selected_Dir, representing the prioritized direction.

❖ Explanation of the above algorithm is as follows:-.

Main Algorithm:

At the initiation of the system, the inaugural step involves the execution of the main algorithm, setting the stage for subsequent operations. The system seamlessly integrates Find_MAX_Dir, retrieving and storing the traffic count for a designated direction in the variable TRAFFIC_COUNT. A pivotal check follows, determining whether the count registers as zero or not. If non-zero, the system seamlessly transitions into the Time Calculation Algorithm, where the optimal signal duration is dynamically computed. The culmination of this process manifests in the dispatch of a signal to the controller, prompting the illumination of the traffic light for the specified direction for the precisely calculated interval. Conversely, when the count is zero, the system gracefully persists in a continuous loop, embodying a perpetual vigilance mechanism. This distinctive and nuanced orchestration establishes a sophisticated and responsive traffic control paradigm, uniquely attuned to the nuances of directional traffic flows.

Dynamic Time Calculation Protocol:

Our cutting-edge Traffic Signal Timing Model dynamically calculates optimal signal durations by intelligently analysing traffic density for specific directions, ensuring a responsive traffic flow. It establishes a baseline time of 15 seconds, with a cap at a maximum of 90 seconds. Real-time vehicle counts trigger additional seconds, fostering adaptability to ever-changing traffic scenarios.

Intelligent Directional Prioritization Strategy:

The Advanced Lane Prioritization Algorithm leverages state-of-the-art image processing for precise vehicle count assessment in each lane. With an initial assignment of zero priorities, it discerns the lane with the highest count, taking into account predefined priorities. A sophisticated scheme dynamically adjusts priorities, giving precedence to high-traffic lanes. This innovative approach ensures equitable opportunities for each lane, minimizing wait times and significantly contributing to the efficiency of traffic control.

IV. EXPERIMENTAL RESULT ANALYSIS

In the dynamic realm of intelligent traffic orchestration where innovation is the heartbeat of progress a ground breaking solution has emerged from a synthesis of insights gleaned from diverse IEEE papers and authoritative books delving into the intricacies of congestion mitigation, a distinctly novel methodology takes centre stage.

Imagine an ecosystem where the pulse is dictated by the nuanced detection of vehicles. This intricate ballet of technology unfolds seamlessly at a pivotal traffic intersection choreographed by a local host. The nerve centre orchestrates a dynamic symphony showcasing a real-time tableau captured by state-of-the-art CCTV cameras. This live visual feed graces a bespoke display known as screen 1, providing a distinctive vantage point into the bustling intersection. This fusion of surveillance and computational finesse paints a one-of-a-kind canvas representing the forefront of avant-garde transportation systems.

Figure 1. Vehicle Detection

Leveraging cutting-edge video image processing, our system ventures beyond the ordinary realm of vehicle identification, seamlessly delving into a realm of precision through an inventive and unique vehicle counting mechanism. This pioneering tech. intricately tallies the vehicular landscape within a predefined Region of Interest (ROI), introducing an unprecedented dimension of pinpoint accuracy and operational efficiency. This fusion of discovery and enumeration not only marks a revolution leap in technology but also pioneers a paradigm shift, reshaping the landscape of how we analyse and enhance traffic flow within designated zones of interest.

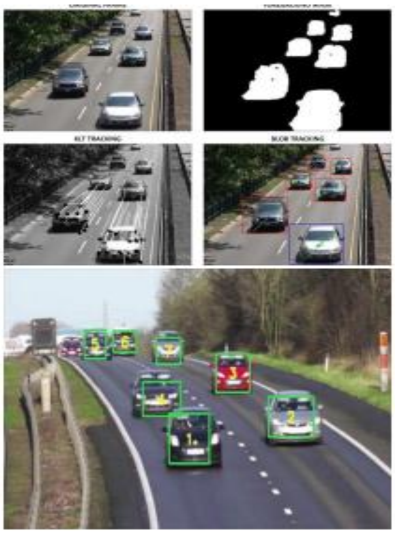

Figure 2. Vehicle counting

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In orchestrating a dance of signals dictated by the ebb and flow of traffic density, our system goes beyond mere vehicle counting. Each vehicle's presence becomes a note in a dynamic symphony, calculating the waiting time for each lane with an innovative precision. The conductor, our controller, then orchestrates a unique signal performance to the traffic lights, guided by a sophisticated algorithm. This fusion of vehicle count analytics and real-time signal modulation not only optimizes traffic flow but introduces a novel cadence to urban mobility management. This seamless integration signifies not just a technological advance, but a nuanced choreography in the symphony of intelligent traffic control.

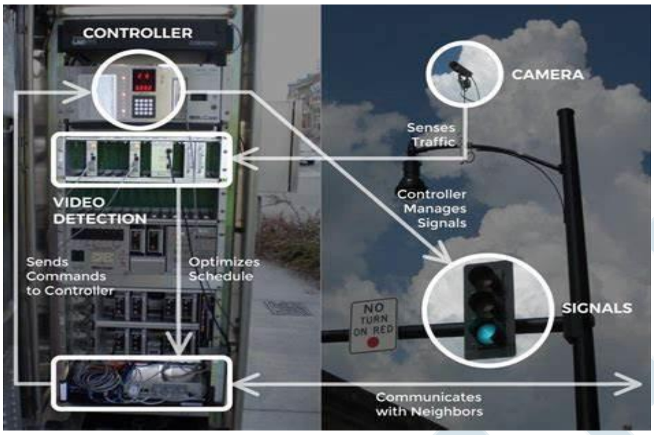

Figure 3. Signal processing

V. CONCLUSION

In this exploration, I unveil an inventive system born from the fusion of Internet of Things (IoT) and image processing. Picture cameras not merely capturing scenes but acting as the eyes for a real-time data symphony. Through this orchestration, our system skilfully computes the average waiting time for each traffic lane, injecting adaptability for heightened feasibility. The allure deepens – low waiting times and enhanced reliability become the stars of our narrative, casting a ripple effect that curtails air pollution and slashes fuel usage. It's akin to a traffic maestro, effortlessly quelling congestion and paving the way for a smarter, more economical traffic management evolution.

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