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Vehicle Engine Stop System with Traffic Signal Break Detection

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***Abstract*— Urban road accidents and fatalities are significantly caused by violations of traffic lights, which in most cases are due to lack of concentration on the part of the driver, tiredness or just failure to comply. The current prevention strategies, which mostly involve human enforcement, roadside red-light cameras, and passive warnings, tend to mitigate concurrent or compound violations in the intricate urban traffic conditions. The paper suggests an integrated, intelligent system, Automatic Vehicle Halt System (AVHS): the system aims to identify, predict, and mitigate several compound violations of traffic law by proactively engaging in a controlled vehicle halt sequence only after determining that the threat is imminent or the offender will continue to violate the law. The AVHS architecture is based on a multi-sensor fusion design that integrates Computer Vision (CV), Vehicular Ad hoc Networks (VANETs) as an infrastructure communication system (V2I) and high- precision Global Navigation Satellite Systems (GNSS). AVHS uses an actual risk assessment model, which is a Bayesian Network to predict the intensity and the possibility of the upcoming violation, as compared to conventional systems,3 which simply record the violations. The paper elaborates on system design, algorithm structure, safety procedures and ethical aspects and concludes with an analysis of the possible effect of the system in curbing the use of severe traffic incidents and improving the consistency of compliance.**

***Keywords*— Traffic Signal Violation, AVHS, Bayesian Network, V2I, GNSS, ADAS.**

I. Introduction

A. Background and Motivation

The safety of urban traffic is a burning issue on the global level. The World Health Organisation (WHO) has identified road traffic injuries as a major cause of death in many parts of the world, and a large percentage of road accidents happen at or close to the signalised crossroads. Signal violations, which cause signal interference, not only disorganise traffic flow but are also one of the main causes of collisions of the type of the side impact (T-bone) or head-on collisions, which are usually the most dangerous kind of collision. Existing enforcement systems like loop detectors or fixed red-light cameras are reactive, and most often they are used in collecting evidence after an incident or to issue a citation after a violation has been made. They also do not consider the more complex, cumulative situations when a driver demonstrates a pattern of several and subsequent violations of signals, which is a sign of high-risk behaviour or incapacitation.

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The proposed Automatic Vehicle Halt System (AVHS) aims to address this shortcoming by introducing an intervening safety layer capable of automatically responding to the acute threat posed by drivers who have gone multiple or continued signal non-compliance.

B. Research Objectives

The major aims of this study are:

- Architecture and design a smart, combined system (AVHS) that has the ability to detect and forecast multi- and cumulative traffic light offences in real time through sensor integration (CV, V2I, GNSS).
- Create an efficient real-time risk assessment model, based on Bayesian Networks and its use to identify when and why autonomous intervention is required, given the severity and likelihood of an impending high-risk event.
- Develop a safe, fail-safe operational procedure of initiating a controlled vehicle stop sequence which will minimise secondary hazards to the breaking vehicle and other traffic.
- Evaluate the effectiveness of the system in preventing severe intersection accidents, as well as enhancing compliance with complex traffic regulations of drivers.

C. Scope and Structure

This paper is devoted to Level 3 and Level 4 semi-autonomous cars that have the required control override features. The paper is arranged in the manner of Section 2 of the review of previous literature. In Section 3, the architecture of the AVHS is described. The algorithm of multi-violation detection and prediction is presented in Section 4. Section 5 outlines the control intervention and stop policy. Section 6 addresses regulatory, ethical and safety implications. Section 7 gives a simulation framework, talks about expected performance, and Section 8 gives a conclusion of the paper.

II. Literature Review

A. Existing Traffic Signal Enforcement and Safety Systems

Traditional approaches to signal violation prevention fall into three categories:

- Inductive Loop Detectors and Cameras: It is a regulatory standard of photo-enforcement cameras (e.g.). Although they are useful in generating revenue and creating post-hoc evidence, they are not applicable in preventing accidents.
- A study by [Clancy et al., 2018] proves that, whereas cameras lead to a reduction of red-light running, at other times, they increase rear-end crashes because of sudden braking.
- In-Vehicle Warning Systems (IVWS): IVWS, such as Intersection Movement Assist (IMA), should send a sound or visual signal in case a fast car is moving towards the red light [Fayazi et al., 2017]. These systems completely depend on the driver's response, which is not very protective when the driver is impaired or deliberately non-compliant.
- Cooperative Signal Systems (C-ITS/V2I): Signal Phase and Timing (SPaT) information can be received by vehicles using short-range communications dedicated to the purpose of cooperative communications (DSRC) and 5G V2X standards. It can be used to implement such applications as Green Light Optimal Speed Advisory (GLOSA) [Barth et al., 2019], which facilitates the smooth movement of traffic but does not enforce its rules against intentional or careless actions.

B. Autonomous Intervention Systems

Autonomous intervention (which is commonly referred to as Electronic Stability Control (ESC) or Automatic Emergency Braking (AEB)) is concerned with physical collision avoidance via proximity sensors [NHTSA, 2020].

Such systems are responsive to an immediate physical hazard (e.g. an obstacle in the immediate path). Before a physical collision, intervention of regulatory non-compliance, however, is less prevalent. The literature on Lane Keep Assist (LKA) and Speed Limit Adherence systems also covers autonomous control takeover; however, it may be opposed by society because of the issue of autonomy in a driver [Goodall et al., 2016]. The special problem of AVHS is the justification of the override on the cumulative non-compliance in the law, and not only on physical proximity.

C. Sensor Fusion and Risk Assessment

The fact that there are several sophisticated violations needs strong data integration.

- ➢ Computer Vision (CV): Deep learning systems (e.g., YOLO, Mask R-CNN) are very useful for object detection (other cars and pedestrians) and the understanding of external signals (traffic lights, lane symbols) [Redmon et al., 2016].
- ➢ GNSS/IMU: High accuracy RTK-GNSS (Real-Time Kinematic Global Navigation Satellite System) is a high precision system that offers good localization (within centimeters), which is needed to determine the position of the vehicle to the stop lines and intersection boundaries with accuracy.
- ➢ Bayesian Networks (BN): BNs are a very useful tool to model uncertain conditional dependencies, which is most useful in synthesizing heterogeneous sensor data and estimating multi-causal risk. [Jensen and Nielsen, 2007] show that they are used in systems with the number of independent factors (speed, weather, signal status, driver state) that cause overall risk probability.
- ➢ The AVHS is the only system that combines all three of these aspects to form a multi-violation state and activate an automated braking system (BN) to initiate a safety-critical override, in contrast to the current ADAS, which prioritizes single threat rejection of a collision event.

III. System Architecture of the Automatic Vehicle Halt System (AVHS)

The AVHS consists of three layers, i.e. Data Acquisition, Central Processing Unit (CPU) and Risk Assessment, and Vehicle Control Interface.

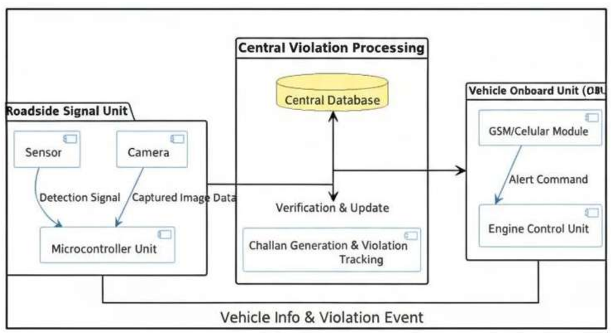

Figure 1. System Architecture of Automatic Vehicle Halt System

A. Data Acquisition Layer

This layer is used to collect real-time data, both internal and external:

V2I Communication Unit.

- ➢ Role: Interprets traffic signal controller data (e.g. red, yellow, green lights and time left) in real time.
- ➢ Data Type: Signal Phase and Timing (SPaT) data.
- ➢ Relevance to AVHS: Gives the external situational awareness of traffic lights. Helps identify compliance with the signal rules of the vehicle. Important to detect possible cases of red-light violations.

Cameras (Front/Side) with a high resolution.

- ➢ Purpose: The system recognises visual objects including traffic light colours, stoplights, road signs, other road users, and pedestrians.
- ➢ Data Type: Image/Video data and Object Bounding Boxes.
- ➢ Relevance to AVHS: Validates or verifies V2I informa tion. Identifies the violations of the human level (e.g. vehicle passing the stop line slowly). Offers graphic impressions that traffic compliance is being checked.

Lidar/Radar.

- ➢ Function: Indicates the distance and the relative velocity of the objects around and the stop line.
- ➢ Type of Data: Infinitely long and Velocity data.
- ➢ Relevance to AVHS: Helps determine impediments dis tance or obstacles. Assists in the prediction of trajectories of the surrounding vehicles and pedestrians. Signals information into the collision-avoiding mechanism.

In-Vehicle Monitoring (IVM)

- ➢ Function: Observes the physical and behavioural condition of the driver (eye movement, head position, steering grip).

- Type of Data: Metrics of Driver State.
- Relevance to AVHS: Knows when the driver is bored or distracted. Gives feed to the risk model of driver inattention to the vehicle. Increases the general security by creating alerts or controlling diversion in case the driver is not fit.

B. Central Processing Unit (CPU) and Risk Assessment Layer

- Data Fusion Module: The module incorporates the heterogeneous sensor data into a single state vector, i.e., the state of the art, i.e. S(t). As an illustration, the state of the traffic light is verified by both V2I and CV, which is redundant and does not cause failure in case the sensor is obstructed or communication is lost.
- Violation Detection Module and Prediction:
  This module operates two functions at the same time:
  - Single Violation Detection Detects instant non-conformance (e.g., going over the maximum approach speed at the current phase of the light).
  - Trajectory Prediction: With the help of the kinematic models, the position of the vehicle, Ppred (t +Delta t), and velocity, Vpred (t +Delta t), are predicted, based on the current driver inputs, and the Time to Stop Line (TTL) and the necessary distance braked (Dreq) are calculated. Violation is predicted when $TTL ¡ SPaT time time left on the current phase and D stop Dreq when the light is red, showing that the vehicle will not safely stop before the intersection and runs the red light.

IV. Safety-Critical Control and Halt Protocol

The main problem of independent intervention is that the action of stopping should not be more dangerous. The AVHS has a two-level intervention procedure (Warning/Mitigation and Controlled Halt).

A. Warning and Mitigation (Soft Override)

Upon MVS activation and on passing through a lower warning point (0.75) by $P H R 1- P HRI allowed to pass through, the system triggers a soft intervention:

- Haptic Feedback: Vibrations on the steering wheel and or the brake pedal to warn the driver.
- Deceleration Assist: The system automatically adjusts the throttle and activates slight regenerative braking (in case of EV/HEV) or a small conventional one in order to help the driver slow down to the needed speed of $D req}.
- Audio/Visual Notice: Putting on the board the message" CRITICAL VIOLATION IMMINENT-AUTOMATIC STOP INITIATED" on the board. On a condition, when the driver performs some corrective measure (e.g. sharp braking or turning the steering), the system restores control.

B. Controlled Vehicle Halt (Hard Override)

When, at time Tcrit, the vehicle path reaches such a point as to cause P HRI above the Halt point, a complete control takeover occurs.

Safety Logic Prior to Halt

The system makes one last check for any hazards before applying harsh braking:

- Rear Collision Risk Assessment: Uses rear-facing sensors and, if available, V2V communication to figure out the $D req} of the cars behind it. If the AVHS-initiated stop predicts an immediate and unavoidable rear-end collision, the system may aggressively turn on emergency warning lights and horns and temporarily delay maximum braking (a "secondary risk minimisation" strategy).
- Clearance Check: Makes sure that the stop will happen before the allowed stop line and not in the middle of an intersection. Here, GNSS accuracy to the centimetre level is very important.

Braking Profile Generation

The AVHS finds the best braking profile $A halt}(t)$ that keeps the ABS from locking up and acting strangely while still getting the car to stop as quickly as possible without going over the safety limits.

Post-Halt State

Once the vehicle has safely stopped before the intersection border, the system locks the controls, keeps the warning lights on, and sends a V2I/V2X notice to other vehicles and possibly to traffic management centers. This notice tells them where the vehicle is and why it stopped on its own. Until the traffic situation goes back to a low-risk state (for example, when the signal turns green and the driver interacts with the system to check readiness), control stays locked.

V. Implementation Considerations and Challenges

A. Real-Time Processing Constraints

The AVHS usually needs a decision cycle of 50 milliseconds to work within strict real-time limits. Both the trajectory prediction and the Bayesian Network (BN) calculation need to be very well-tuned. To get the needed throughput, the BN must be set up with either specialised inference hardware (FPGAs) or pre-computed Conditional Probability Tables (CPTs).

B. Environmental and Sensor Robustness

Fog, heavy rain, snow, and glare from the sun are all examples of environmental factors that can have a big effect on the performance of a CV system.

- Light Status Ambiguity: In tough situations, CV needs to be able to tell the difference between red, yellow, and green lights. This requires combining V2I data with advanced image processing algorithms, like spectrum analysis.
- GNSS Integrity: Urban canyons and tunnels may cause GNSS signal degradation. In order to maintain high-accuracy placement near intersections where intervention is critical, the system must employ simultaneous localisation and mapping (SLAM) techniques and Inertial Measurement Units (IMU).

C. Cyber Security and Trust

Overrides for autonomous systems are extremely vulnerable to cyberattacks (such as faking V2I signals or interfering with control orders). Strong cryptographic authentication for all V2I communications and separate, secure operating environments for the control CPU are required by the AVHS. By making sure the intervention is predictable, only takes place in cases of significant safety concern, and is always reported and auditable, trust is preserved.

VI. Ethical and Regulatory Framework

The installation of an automated, mandatory vehicle-halt system raises serious ethical and legal issues about driver autonomy, accountability, and system culpability:

A. Driver Autonomy vs. Public Safety

The AVHS is predicated on the notion that the overall benefit of preventing major collisions surpasses a driver's right to complete, unimpeded control when that right is obviously a serious risk to public safety (MVS state). This is similar to laws imposing speed limits or seatbelt requirements, which limit individual freedom for the good of society.

Requirement for Intervention Based on the multiple violation status, the system must be legally verified to only take action when the likelihood of a high-severity accident exceeds a regulation threshold ($θ Halt}).

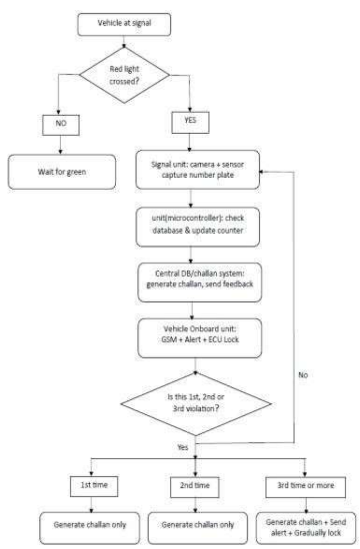

Figure 2. Flowchart of Automatic Vehicle Halt System

B. Data Privacy and Logging

Every intervention event, along with any relevant sensor data (GNSS track, pre-halt video, driver condition), must be securely documented as an immutable "Black Box" record. For post-event analysis and accountability assessment, this knowledge is crucial. Strict data anonymisation protocols must be adhered to in order to protect driver privacy, and only when an incident has been confirmed may law enforcement or regulatory bodies access complete data.

VII. PERFORMANCE EVALUATION AND DISCUSSION

A. Simulation Framework

Since it is not feasible to verify high-risk intervention logic in the real world, evaluation of the AVHS requires considerable simulation. It is necessary to have a microscopic traffic simulator (such as SUMO or VISSIM) that is supplemented with realistic sensor noise and high-fidelity vehicle dynamics models.
Important Metrics for Simulation:

- Accident Reduction Rate (ARR): The proportional drop in high-speed junction and simulated T-bone collisions that occurs when AVHS-equipped cars are introduced.
- False Positive Rate (FPR): The frequency of needless interventions (halting while no actual high-risk violation was impending) is known as the False Positive Rate (FPR). To keep users' trust, a low FPR is essential.
- Intervention Success Rate (ISR): The percentage of effective halts that result in the vehicle safely halting ahead of the stop line following a real MVS incident is known as the Intervention Success Rate (ISR).
- Secondary Accident Rate (SAR): The rise in rear-end incidents brought on by the AVHS-initiated stop is known as the secondary accident rate.

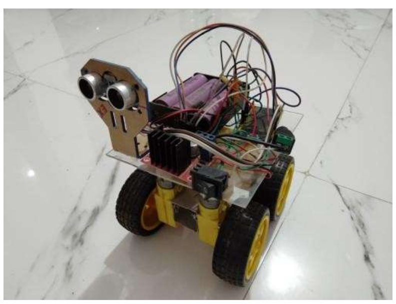

Figure 3. Signal Detection Vehicle

Figure 4. Traffic Signal Control Vehicle

B. Expected Performance Gains

If the AVHS is implemented successfully, significant safety improvements are expected:

- Targeted Prevention: By focusing on the cumulative risk factors (MVS), the approach prevents the most dangerous driving habits, which are often linked to drunk or very negligent drivers.
- Consistency of Compliance: Compared to human enforcement, the AVHS's objective, 24-hour enforcement greatly increases compliance rates at equipped junctions.
- Decreased Deaths: Since signal breaches are closely linked to high-speed, side-impact collisions, a decrease in these instances is anticipated to result in a comparable decrease in fatalities and serious injuries.
- Hypothetical Comparison: Simulations based on similar AEB systems suggest that concentrating on the high-risk edge cases managed by MVS might lead to a 15–20% reduction in intersection mortality among the fleet of equipped vehicles if the FPR remains statistically insignificant ($≤ 0.1%).

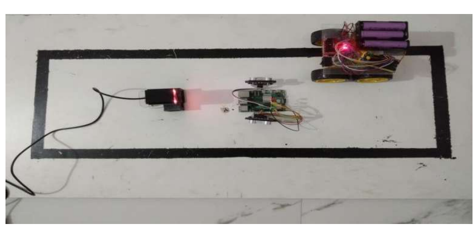

Figure 5. Vehicle Engine Stop System

VIII. CONCLUSIONS

The fatal and enduring issue of serious traffic signal violations has a new and proactive answer in the form of the Automatic Vehicle Halt System (AVHS).

AVHS goes beyond reactive monitoring by combining multi-sensor data fusion, V2I communication, and a sophisticated Bayesian Network Risk Assessment Model to forecast and avoid high-risk, multiple signal violations intelligently and autonomously. Safety-critical redundancy is incorporated into the controlled halt protocol's architecture to assure the prevention of the primary violation while minimizing sec ondary hazards. Although there are many technical obstacles to implementation, especially with regard to robust real-time processing and sensor dependability in challenging conditions, the biggest obstacle is creating a transparent, globally recognised regulatory framework that strikes a balance between driver autonomy and the need for public safety.

In order to ensure that surrounding traffic is alerted and ready for the autonomous halt event, future research should concentrate on optimising the BN parameters through comprehensive field data collection of near- miss scenarios and further improving the secondary risk minimisation protocol to incorporate predictive V2V coordination. With its promise of a major decrease in urban road trauma, the AVHS is an essential advancement in traffic safety technology.

REFERENCES

[1] Barth, M., et al. (2019). Cooperative Intelligent Transportation Systems: Safety and Operational Benefits. IEEE Transactions on Intelligent Transportation Systems, 20(3), 856-869.

[2] Clancy, K., et al. (2018). Red-Light Camera Effectiveness: A Comparative Analysis of Accident Types. Journal of Transportation Safety & Security, 10(4), 301-318.

[3] Fayazi, A., Vahidi, A., & Pisu, P. (2017). Predictive Intersection Movement Assist: A Vehicle-to-Infrastructure Approach. Vehicle System Dynamics, 55(4), 583-605.

[4] Goodall, N. J., et al. (2016). Ethical Review of Autonomous Vehicle Safety Standards. Accident Analysis & Prevention, 92, 11-20.

[5] Jensen, F. V., & Nielsen, T. D. (2007). Bayesian Networks and Decision Graphs. Springer Science & Business Media.

[6] NHTSA. (2020). Automatic Emergency Braking System Performance Assessment. National Highway Traffic Safety Administration.

[7] JRedmon, J., Farhadi, A. (2016). You Only Look Once: Unified, Real-Time Object Detection. Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 779-788.

[8] J Zhang, X., et al. (2021). The intelligent engine start-stop trigger system based on — proposes trigger logic for start/stop based on traffic/stop conditions (useful for engine-stop algorithms).

[9] Aliane, N., et al. (2014). A System for Traffic Violation Detection. — experimental ADAS/platform for detecting traffic violations (foundation for red-light detection modules).

[10] Agarwal, P., et al. (2018). Implementing ALPR for detection of traffic violations: a step — automatic license-plate recognition methods for enforcement (ANPR is core to linking violations to vehicles).

[11] Alzamzami, O., et al. (2025). Passable: An Intelligent Traffic Light System with Integrated — modern adaptive traffic-signal systems using CV and wireless comms (context for coordinating signal + vehicle units).

[12] Yadav, A. (2019). RFID: Future of Red-Light Violation Detection System. — explores RFID alternatives to camera-based detection (useful for vehicle-to-infrastructure linking).

[13] Karrouchi, M., et al. (2023). Practical investigation and evaluation of the Start/Stop — experimental evaluation of start/stop systems (performance and user/vehicle impacts).

[14] MDPI (2025). Safety Effectiveness of Automated Traffic Enforcement. —arecent review of ATES outcomes and limitations (policy, accuracy, social impact).

[15] Karrouchi, M., et al. (2023). Practical investigation and evaluation of the Start/Stop — experimental evaluation of start/stop systems (performance and user/vehicle impacts).