An On-board Semi-Autonomous Mobility Override System based on V2X Platform

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ABSTRACT: The ATTMS systems have been in existence since the early 2000s. These systems have been able to detect the flow of traffic networks and provide extensive information to create smarter and safer transportation networks. These systems have evolved in the past two decades in terms of the sensing capabilities, advanced computational methods and control strategies. These systems differ at various places based on the topography, traffic flow density and climatic conditions. Local traffic authorities work in high coordination with the input of these systems to execute law and order to the fullest and also to control and divert the traffic in a more effective and efficient way. In this paper, an application of these ATIS systems [1] has been proposed which facilitates override of maximum highway speeds of vehicles on a macroscopic and microscopic scale. This enables control and diversion of traffic.

INTRODUCTION

Various applications of ATTMS exist with an emphasis on real time detection and control of vehicles in the V2X domain. This shared information system helps every single vehicle, commuter, pedestrian etc. to commute better and safer. The horizon of smart systems is too large and it evolved with the advent of any new technology or mode of communication. For example, the earlier versions of GPS [2] used CDMA [3] signals for communication which was not sufficient to provide accurate location. These days we have seamless connectivity through 4G LTE networks which transmits large amounts of data for better and accurate prediction.

Various such systems have been built in the past decades with progressing communication technologies. With the evolving capabilities of microprocessors, it became possible to construct various complex systems which controlled the vehicle in a specific operating condition. This paved the way for various smart mobility systems and created the domain of autonomous driving. Although we have not yet attained SAE Level 5 driving automation, we are progressing towards it. These autonomous vehicles will need a platform which is commonly referred to as V2X platform these days which will provide the vehicle various necessary information to take logical decisions in real time and provide a safe Mode of mobility. This is an iterative process because automotive companies these days are hesitant to fully equip their vehicles with autonomous capabilities. This is mainly because of their inefficient operation in the evolving V2X platform [4]. On the other hand, the local authorities are yet to build a good infrastructure to host autonomous mobility. This is a closed chain cycle which will evolve simultaneously. Also it will need approval from the traffic authorities and acceptance from people to fully trust and use these technologies for daily commuting.

Until then, automotive companies have come up with their own technologies in the ADAS domain [5] which require human intervention for its operation and control. Here we can say that we are currently on SAE Level 1 automation level when it comes to the majority of the mass scale traffic population. It is expected that by the end of this decade, the old conventional vehicles will vanish and these ADAS equipped vehicles will dominate the market which will make progressive developments from Level 1 to Level 2 or 3. There can be certain exceptions where certain automakers would take the lead to develop Level 4 equipped vehicles to gain monetary advantage in the sales market. But when it comes to road safety, there is still a lot to explore and develop.

When we talk about the ADAS equipped vehicles which have systems like adaptive cruise control, blind spot detection etc. they reduce human effort and provide a comfortable driving experience. But since the decision maker is the driver, the control of the vehicle is based on the driver's driving strategies. Here we might face some Human factors issues like neglecting warning signals from the system due to driver fatigue or taking a wrong decision which will lead to a dangerous scenario for the surrounding vehicles etc. In this domain, the human involvement is high and to override such unnecessary human errors [6], an override system by the vehicle or the traffic authorities should be introduced to control the vehicle's irrelevant activities. This can be done easily with the help of ATTMS systems in the V2X domain.

PROPOSED CONCEPT

In this paper an idea to override the human control input on the vehicle by the traffic authorities has been proposed which will allow better control of vehicle/s in a dangerous situation. This can be done by creating an ITS system which will override the human input and will control the vehicle on a microscopic (a particular vehicle) or macroscopic (a large portion of vehicles) scale to provide easy and efficient flow of traffic. The block diagram shows the concept.

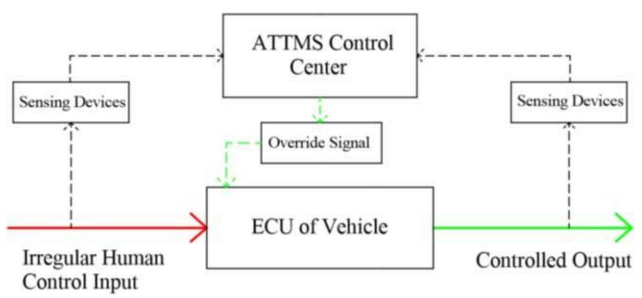

Figure1: Process block diagram of the proposed concept

The concept is based on the ATTMS platform which enables easy sensing and monitoring of vehicles on highways. This is primarily used to collect data about the vehicle speed, location, fuel level, tire health condition etc. with this information Dead Reckoning (DR) can be performed to conserve energy and prevent excessive signal traffic. This DR allows us to predict the expected vehicle location and speed at regular intervals. This helps us track the vehicles with ease.

The idea here is to sense and control the vehicle/s if they exceed the regular traffic instructions on a highway.

Microscopic Control: If a particular vehicle behaves irregularly by exceeding the speed limit or changing lanes dangerously, it will lead to a situation where the driver input becomes lethal for the surrounding vehicles. Hence the system senses the vehicle's irregular behavior and hence sends an override signal to block the human input. Here the vehicle can be either stopped or allowed to maintain its flow with the traffic by driving at a constant speed and in a single lane. This will prevent disturbance in traffic flow and the vehicle will be controlled from the control room until it reaches the nearest police station or hospital to attend criminal or medical emergencies respectively.

This evacuation can be done through the Emergency Vehicle Rescue System (EVRS) as shown below. The target vehicle is pulled out from the moving traffic and is done with the help of an override signal which drives the ADAS systems like lane shift assist and cruise control. This evacuation is done in steps which will be coordinated in the moving traffic to facilitate easy passage of vehicles. The target vehicle and the surrounding vehicles which are controlled by the control room are maneuvered safely to attend medical, criminal or technical emergencies.

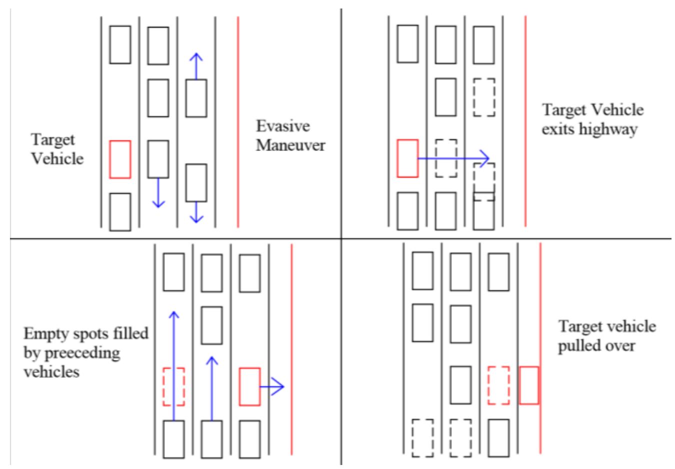

Figure 2: Microscopic control and evacuation of target vehicles from moving traffic.

Macroscopic Control: If a particular group of vehicles are meant to be slowed down or diverted to an alternate route due to an emergency ahead, macroscopic control of vehicles can be done by sending override signals to all the vehicles which will attain a disciplined platoon which is controlled by the traffic authorities. This spacing between each vehicle based on its length and field of view of the driver can be easily adjusted by the vehicle. The speed of this controlled platoon can be maintained or varied in the most efficient and safest way to save energy. This platoon can also be diverted to reduce traffic density and ease out the flow in constrained areas.

Another application of the Macroscopic Control is called Anti-Platooning Oscillation Prevention (APOP). This can be explained below. Suppose there is a roadblock a few miles ahead on the highway and a diversion is being arranged by the traffic authorities which will take time to arrange. Meanwhile the traffic approaching at high speeds which are controlled by various humans will brake and decelerate at different rates leading to a haphazard movement in the traffic flow called as platooning oscillations. These oscillations are quite economically expensive as it requires constant acceleration and braking which lowers fuel economy and also creates an uncontrolled situation on the highway.

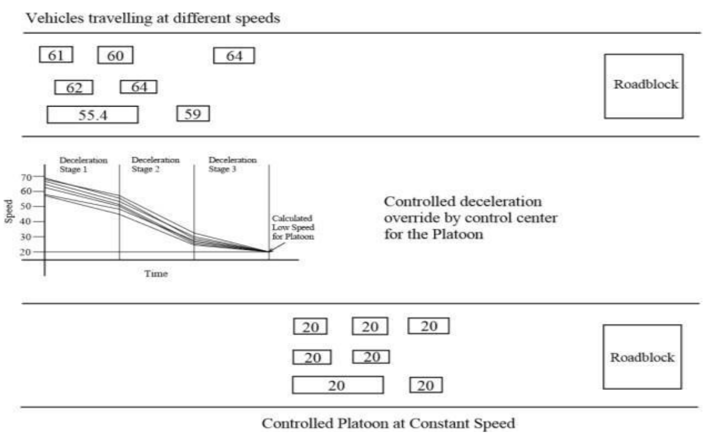

Figure 3: Macroscopic platooning Oscillation Prevention

To avoid this, the APOP system will first calculate the distance of the traffic from the roadblock. Based on this data and the average velocities of the vehicles, a controlled deceleration signal is sent to the vehicles which performs the braking action and lowers the speed to attain a uniform platoon of vehicles which is free from oscillations. Here since the rate of deceleration is calculated in real time from the control room, the deceleration rate is low for the vehicles in the front and the rate increases for the preceding vehicles. This not only damps the platooning oscillations, but also conserves a lot of energy and time. If we don't have a smart infrastructure, the vehicles can solely rely on ADAS technologies to reduce the platooning. In this case the damping of oscillations won't be as effective as APOP it will reduce the high discrepancies in the vehicle control when controlled by a human.

This proposed concept relays control override signals from the control room to the vehicle via GPS or Internet connectivity. The detailed model of this signal transmission is out of the scope of this paper. Hence to realize this concept, the idea is pitched and the control override signal is transmitted to the vehicle. The vehicle's ECU then controls the vehicle's propulsion activities by braking, accelerating or changing lanes. To control the vehicle's speed, throttle control system is demonstrated where the system based on the override input lowers the speed of the vehicle and hence carries out the vehicle mobility as planned by the control room.

INTEGRATION OF SENSORS AND ACTUATORS

For this type of application, the primary sensors to be used are cameras and RFID tags. They are installed at regular intervals to allow easy counting and calculation of vehicle speed in a moving traffic. Also the GPS location of each vehicle in the time domain also serves as a valuable input in this case since it gives the instantaneous velocities of the vehicles.

The actuators used for controlling the vehicle remotely are primarily throttle control, steering control and braking. They can be linear actuators or rotary actuators like motors. In this paper, the electronic throttle control is presented and hence motor is our main actuator in this case.

ELECTRONIC THROTTLE CONTROL (ETC)

The throttle body of the vehicle controls the amount of fuel entering the engine. This is controlled electronically by a motor which directly controls the throttle angle of the throttle body thereby providing a much better and economical throttle operation based on the driving demands of the vehicle. The Electronic Throttle Control is a unit that is usually a drive-by-wire system which controls the vehicle's acceleration.

The electronic control of the throttle body is not as easy as it sounds. First the throttle body is designed as per the engine's displacement, and then the mechanism of

The throttle opening and closing is designed. Since the mechanism consists of interconnected parts like liver and springs, the system becomes less responsive when controlled from the motor due to non-linear effects of static friction, spring constant etc. [7]. To avoid this, first an experimental identification of the system needs to be done in order to study the lag of the system. Then the controller needs to be designed in such a way so that the throttle body opens at the right time at the right angle to allow the correct amount of fuel to enter the engine.

To control the throttle with the help of a motor, a PID controller is used which is tuned to attain stable operation.

Throttle Body Design

The throttle body is a circular disk which is placed between the air inlets to control the air fuel mixture.

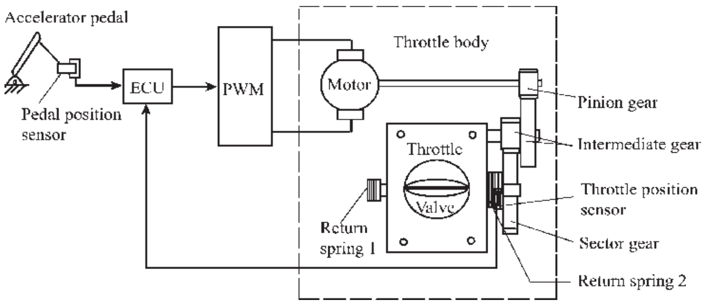

Figure 4: Diagram of Throttle body

The throttle body should create a clearance fit with the throttle bore to allow easy opening and closing of the throttle. The diameter of the throttle bore is given by

$$D = \sqrt{4 . \frac{Vdisp.\frac{N}{2}.\eta vol}{cd.\pi.Vt}}$$

Where V_{disp} is displacement of engine, N is engine speed, η_{vol} is volumetric efficiency of engine, C_d is discharge coefficient and V_t velocity of entering air. Based on the engine parameters, the throttle body is designed and then the controller is designed.

PID Controller

A PID controller is designed for this application which is as shown in the figure.

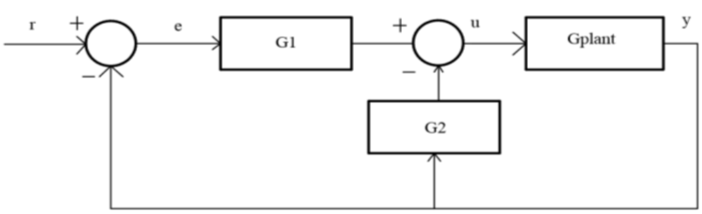

Figure 5: PID Controller Structure

Here y is the output, u is the control input, G plant is the plant model, G1 and G2 is the PID controller, e is the error and r is the reference signal. After derivation, the PID controller is defined as follows

$$G1 = kp+\frac{ki}{s}$$

$$G2 = \frac{Kd.s}{100(0.001s+1)}$$

Software Design:

A Simulink model is created and the PID controller module is connected to the plant to create a feedback control system. A step input is chosen as an input to the model and the values for Kp, Ki and Kd were tuned to obtain the best response.

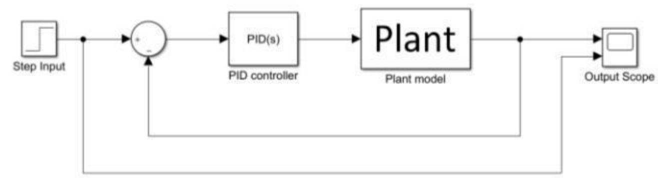

Figure 6: Simulink Model

RESULT

The result shows a good response of the PID controller in controlling the throttle. We obtained a smooth response and the PID control parameters were optimized. The motor controls the throttle body with ease and facilitates easy opening and closing of the throttle at the right time.

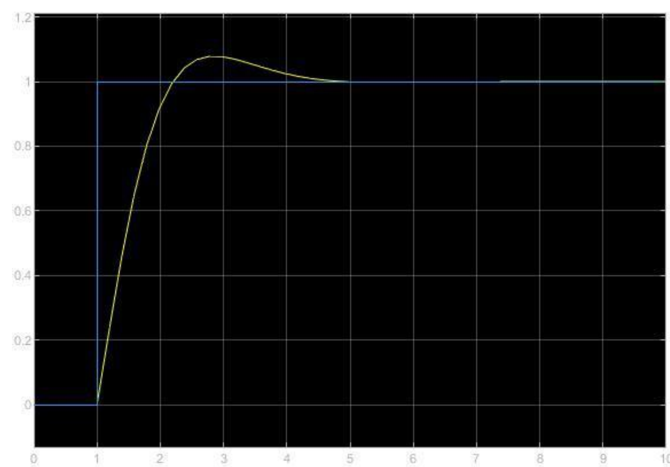

Figure 7: Step response

CONCLUSION

In this paper a concept of Override system was proposed which was intended to control irregular behavior of vehicles on highway due to human input or error. The scope of this paper is limited to projection of concept and simulation to prove the functionality of the concept. The concept was explained which shows the control of the vehicle in a macroscopic and microscopic mode. This is primarily done by controlling the speed and direction of the vehicle. To reduce the human error, an override signal is sent to the vehicles which operate and control the vehicle or vehicles as per the instructions of the control room. This is demonstrated in this paper by showcasing the modeling and simulation of an electronic throttle control. A Simulink model was created which shows the functioning of the controller and a step response was obtained. Similarly other functions of the vehicle such as steering control can also be controlled remotely by the control room.

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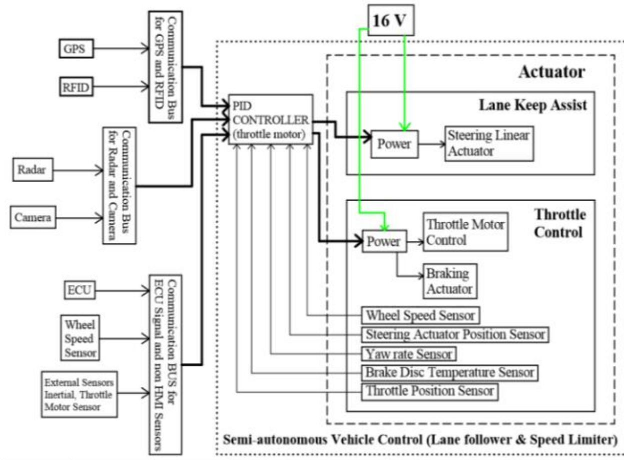
DFMEA

BOUNDARY DIAGRAM



FMEA Ref.	Item/Function	Potential Failure Mode	Potential Effects of Failure	SEV	Classifin.	Potential Cause of Failure	Occurance	Current Design Controls (Prevent or Detect)	Detection	RPN	Recommend Actions
1	**GPS** - *It is a satellite navigation system that provides location, velocity and time synchronization*	Signal Loss	Loss of Navigation and Vehicle Path	8	KPC	Equatorial Plasma Irregularities or EPIs occurring in the ionosphere's F region can cause GPS signal loss.	3.5	Wait for signal to restore. Reboot GPS	4	**112**	Backup RFID Signals to limit the speed of vehicle in the lane
2	**RFID** - *It is uses electromagnetic fields to identify and track tags attached to objects.*	Reading error	Incorrect information being transmitted to vehicle's ECU	10	KPC	Damaged tag	4.5	Read signal from the next RFID module in the lane	3	**135**	Backup GPS or Radar to detect distance from nearby vehicles
3	**Radar** - *It is a detection system that uses radio waves to determine the range, location or velocity of objects.*	Electrical components failure	Sensor output equal to the maximum or minimum of that sensor	7	KPC	Due to hardware failure	3	Replace Radar	3	**63**	Secondary Backup Radar
4		Clutter Effect	Serious performance issues with radar systems	6	KPC	Caused by a long radar waveguide between the radar transceiver and the antenna	3.5	Wait for signal to restore. Reboot radar	2	**42**	Reset Radar
5	**Camera** - *It is an optical instrument used to record images.*	No Image Processing	Loss of Visibility or blurred image	10	KPC	Lens covered with dirt or foreign particles	4.5	Remove dirt and clean surface	5.5	**247.5**	Hydrophobic Film on Camera Lens
6		Image disparities	Blurred Image due to variable refractive index	8	KPC	Water Intrusion inside Camera	7.5	Restart the camera and provide warning to driver	4	**240**	Waterproofing the camera
7		Distorted Image	Unclear images	9	KCC	Vibrations	3	Reduce excessive accelerations to reduce vibrations	3.5	**94.5**	Adding cushions to damp vibrations
8	**Wheel Speed Sensor** - *It is used to determine the speed of wheel.*	Power supply to sensor system fails.	No measurement of input signal	6	KPC	Wire defect	6	Replace wire	4	**144**	Use good conductor
9		Crucial electronic components	Incorrect output	7	KPC	Due to hardware failure	3	Replace sensor	3	**63**	Change wire
10	**Wire** - *It is used to transmit electrical signals within the system*	Mechanical disconnection	No signal processing or transfer of information	8	KPC	Overheating or Loose Connections / Solder failure	5	Screw down the connections	2.5	**100**	Solder connection
11		Faulty Connection	Loss of Signal and inefficient transfer of information	9	KPC	Corrosion at wire terminals	2	Troubleshoot system with test signal. System reboot	2	**36**	Solder connection or change wire

ACRONYMS

ATTMS: Advanced travel and traffic management system

V2X: Vehicle to Everything

ADAS: Advances driver assistance systems

GPS: Global positioning system

CDMA: Code-division multiple access

LTE: Long-Term Evolution

DR: Dead Reckoning

EVRS: Emergency Vehicle Rescue System

APOP: Anti-Platooning Oscillation Prevention

PID: Proportional integral derivative controller

BIOGRAPHIES

Prajwal Lamichhane is an under-graduate pass-out student on Mechanical Engineering from Visvesvaraya Technological University (Belagavi) in 2017. His interest are Automobile and Safe Transportation.

Nischal Kharel received the BE in Mechanical Engineering degree from Visveswaraya Technological University. He has a keen interest on Aeronautics, Research on Material Testing, and Design of Components.

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