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Tittle: Human Driven and Autonomous Vehicle-Intersection Coordination Scheme With and without Traffic Light.

1 Introduction

There has been an established worry over road traffic control system due to constant traffic congestion caused by increased population and urbanization. However, it has become hard for traffic controllers to provide safe and efficient traffic movement on the streets at the same time. The connections of different road paths make intersections, where the possibilities of vehicle collision are critical without good control measure. Traffic congestion often occurs when traffic density becomes higher than the capacity of a road or road network. Efficient use of the existing road infrastructure by innovative intersection management and control is a solution for the cities where further construction and expansion of roads are difficult. Conventional vehicles have road traffic intersection control measures of using traffic light system, while the driver-less vehicles came in with new technology for accessing the road facilities involving vehicle-vehicle and vehicle-infrastructure communication, while Human driven vehicles involves driver-to-road infrastructures communication. Considering the fact that the introduction of new technology is not automatic and the current technology will be replaced by news one gradually, hence the need for the integration of driver-less vehicle movement parameters with that of human driven vehicle to midwife the smooth transition to a fully automated or smart city. This is necessary because conventional vehicles which are currently occupying the road cannot just be phased out sooner. Realistic point of few has it that a new technology which will phase out the existing once will normally take some time for the integration and acceptance because in most human driven vehicles users believes in the way they used to do it and cannot afford to do away with their private vehicle immediately even with some government incentives if available. Gradual transformation to a fully automated road transport system can seamlessly be achieved by integrating the attributes of automated vehicles into the human driven vehicles bearing in mind the human driver's attribute on road (tracking user's behaviour) which is stochastic in nature. Among all the controlling methods of traffic de-congestion, the traffic light signalling method is the most effective and secure, but this traditional method increases the amount of delay time, and for that reason, various automated vehicles and semi-automated ve-

hicles will be faced with various delay problems.
An early approach to automation in the field of vehicles started with the Automated Highway System (AHS) research program[20], it was focused on the improvement of the capacity and the safety of the highway traffic. The efficient scheduling of the traffic lights system at road intersection can only guarantee an optimal utility of the road infrastructure at the point of intersection[44]. The advent of automated vehicles led to the birth of vehicle-to-vehicle and vehicle-to-infrastructure communication which inadvertently led to road intersection settings without traffic lights but has smooth and efficient flows of traffic with good safety measures. There is no doubt in saying that connected and automated vehicles (CAVs) have the potential to improve safety by reducing and mitigating traffic accident with seamless flow of traffic with good safety measures.
In the traditional traffic control paradigm, traffic flows at intersections are regulated by traffic lights or signs that restrict the maximum traffic handling capacity of the intersections and increase inconveniences of frequent stops and idle time. Vehicles at a stop sign must come to a complete stop before crossing, even if no other vehicle is present at the road segment thereby causing traffic delay. In a similar way but without any traffic sign, traffic entering the roundabout must yield to traffic already in the circle. At busy intersections, flows of vehicles on each approach are usually regulated by green and red lights that eventually increase the stop delays. Among the various methods of alleviating traffic congestion, traffic-light or signal control is commonly considered as the most effective method, and various strategies for urban traffic management have been developed based on this approach[40, 50, 24]. These signal control strategies can only partially improve the traffic flow if all approaches to the intersection are not equally congested, and they cannot eliminate the stop delay of vehicles at intersections regardless of traffic volume. Considering increasing trends of vehicles and sustainability of the road transportation system, a breakthrough in the intersection control paradigm which may eliminate the necessity of stop and increase the capacity of intersections, is highly expected. Semi-automated vehicles are already emerging in the market, and it is expected that fully automated vehicles will be widely used in the near future considering the advancement in sensor technology and adoption of communication technology.
The scheme efficiently utilizes the intersection area by preventing each pair of conflicting vehicles from approaching their cross-collision point (CCP) at the same time, instead of reserving the whole intersection area for the conflicting vehicles successively. Moreover, the introduction of relevant constraints ensures the scheme is free from any collisions and enables it to manage turning movements of the vehicles under a safe velocity limit. Turing vehicles sometimes need special treatment so that multiple vehicles slowly and closely cross the intersection, which is realized in the VICS. An intersection coordination unit (ICU), which is installed at the intersection, uses two-way communication to receive basic driving information from the approaching vehicles, e.g., current position, velocity, and destination at the next intersection and sends guidance to them after computing their control inputs. In the scheme, a risk function is proposed

that explicitly indicates only a portion of the intersection by quantifying the risk of a collision of a pair of vehicles around their CCP. More specifically, at any time, if two conflicting vehicles are very close to their CCP, the risk function returns a high value, and if at least one vehicle is far from the CCP, the risk value returns a negligible value. Considering states of all vehicles, a constrained nonlinear optimization problem is solved in a model predictive control (MPC) framework in order to let the vehicles cross the intersection rapidly by minimizing the total quantified risks of all vehicle pairs. Minimization of risks helps in generating safe trajectories of vehicles by reducing unused time and space in the intersection area and consequently, enhances the traffic handling capacity of the intersection and improves traffic flows. However, the scheme integrates fully automated vehicles intersection to improve traffic operations. The proposed VICS will be evaluated through numerical simulation and its performance is compared with the traditional signalized scheme. Under the various traffic-flow conditions, the key interest is to observe that the stop delay of vehicles at the intersection is almost eliminated and flows of vehicles and the capacity of the intersection are significantly improved. The semi-automated and the fully automated vehicles are controlled by the sensor technology with communication languages. The communication must happen between vehicle to vehicle or vehicle to infrastructure seamlessly.

Autonomous vehicle intersection scheme with light and lightless under a connected vehicles environment that overcomes the limitations of the existing methods is proposed. The novelty of the proposed scheme is the global coordination, by considering the states of all vehicles together, based on avoidance of their cross-collision points. However, considering the increasing trends of vehicles and sustainability of the road transportation system, a breakthrough in the intersection control methods, which may eliminate the necessity of stop and increase the capacity of intersection, is highly expected. Conventional drivers of vehicles create traffic congestion due to the various types of disturbances, therefore, people on daily bases waste a considerable amount of fuel and time, and that is why the cost of traffic increases day by day. Exceeding the number of vehicles meant for a road capacity is the main reason for traffic congestion as the density of traffic is higher than the road network capacity in most cases. In this situation, if the existing road network is used in a very innovative way, then this problem situation can be solved. Management of intersection and various controlling methods is a feasible solution of such problems.

However, to control traffics at intersections without traffic light, various mathematical parameters are involved which are related to the interface of the vehicles being control. Geometry is one of the important tools which is used here to control the traffic without the light signals. These parameters are classified according to the movements of the system. There is a potential cause of harm in safety-critical situations for Artificial intelligent system such as autonomous driving which has been gaining research attention. For instance, decision making at intersections in autonomous vehicles is either solely based on machine learning, through end-to-end intersection control unit, or involves some combination of logic-based reasoning and machine learning components, where an image classifier produces a classification, say speed limit or a stop sign, that serves as input to a controller [22, 2, 45]. A system that was able to detect that presence of another vehicle approaching a cross was developed [35, 11, 58, 15]. Lane detection scheme is very important in road transportation system especially as it regards autonomous vehicle for essential lateral services such as lane departure warning system and lane keeping assistance system. Furthermore, detected lane could be considered as an indication to vehicle's further driving path as it could be a principal criterion to decide how forward obstacle could be affected or not. In another word, lane detection could not only affect longitudinal systems such as autonomous emergency braking system, forward collision warning system, and adaptive cruise control system but also indirectly affect full spectrum of the automated driving system[47, 12, 29, 46]. Risk factors associated with autonomous vehicle sensor failures can be mitigated by using the method of single failure assumption which states that at most one sensor can fail at any time, however, the detection of the failures in autonomous vehicle sensors systems is generally carried out by simple algorithms which can improved our objective to developed a model-based fault-tolerant control-scheme for vehicle lateral dynamics control. This approach can detect and identify sensors failures right after failure has taken place. Then the output of the faulty sensor is reconstructed from the output of the healthy ones [39, 28, 48]

2 Review of Related Literature

Considering increasing trends of vehicles and sustainability of the road transportation system, a breakthrough in the efficient use of the existing road networks by innovative intersection management and control is inevitable especially for the cities where further construction and expansion of roads are difficult. Unlike autonomous vehicles whose movements can be well manipulated or controlled seamlessly, human driven vehicles usually do not follow control laws and their movements involve a high level of uncertainty and randomness because of the human attitude to driving. Quite a few simulation studies have shown that human driven vehicles will impair the performance of autonomous vehicles at road intersections[9, 36, 52, 54].

In the traditional traffic control paradigm of using lights, traffic flows at intersections are regulated by traffic lights signals or signs that restrict the maximum traffic handling capacity of the intersections and increase inconveniences of frequent stops and idle time [40, 50, 24]. Traffic signal control strategies can only partially improve the traffic flow if all approaches to the intersection are not equally congested, and they cannot eliminate the stop delay of vehicles at intersections regardless of traffic volume. Several conditions can trigger the deceleration process, for example, a driver has to slow down and eventually stop at a signalized intersection according to traffic rules. The deceleration process could be developed into two stages;

1) The first stage, drivers released the throttle pedal, and applied the brake

pedal if a higher level of deceleration is required, to slow down until the speed reached zero.
2) Drivers waited for a while until the light turned green[57]. It is a fact that different drivers can obtain different fuel consumption figure on the same journey and same type of car due to their individual attitude to driving. The European Traffic union project was initiated in 1986 as part of highest efficient and unprecedented safety research project whose output will be a common traffic technological platform to be used in turn by the participating countries once the product development phase begins, which was aimed at the following: improved driver information, active driver support, cooperative driving within vehicles and lastly Traffic and fleet management[6].
Studies on innovative intersection management have been found in the literature that attempt to control vehicles without using traffic signals. Current methods of lightless intersection scheme for autonomous vehicles can be categorized as shown below .The systematic review of human driven and automated vehicle intersection coordination scheme was based on the guide line from the below table of review summary.

- Centralized method: Centralized approach keep the same approach as the traffic lights but include Vehicle-to-Infrastructure (V2I) communication. It typically involve an intersection agent (IA) that receives requests from vehicles to cross the intersection, do the scheduling and decides the best crossing sequence. [13]
- Decentralized method: The decentralized approach uses vehicle-to-vehicle (V2V) communication coordination without traffic lights or manager, instead it allows the vehicles to cross the intersection without having to predict the future trajectory while crossing.

2.1 Fuzzy-based intersection control

The fuzzy-based intersection control was successfully demonstrated and its performance with autonomous car and a human driven car on an actual secured test bed was observed. While the manual driven car showed the significant fluctuations of the speed when crossing the intersection, the autonomous car maintained its speed resulting in no stops at the intersection area [35, 18, 21, 7, 34].

2.2 Model Predictive Control

Considering states of all vehicles, a constrained nonlinear optimization problem is solved in a model predictive control (MPC) framework in order to let the vehicles cross the intersection rapidly by minimizing the total quantified risks of all vehicle pairs. Minimization of risks helps in generating safe trajectories of vehicles by reducing unused time and space in the intersection area and, consequently, enhances the traffic handling capacity of the intersection and improves

Table 1: pro's and cons matrix
and cons matrix.PNG

METHOD	PRO'S	CONS
Fuzzy-based intersection control	Reduce waiting time and improve fairness	Difficulty in determining the appropriate size of traffic groups at real-time traffic
Model predictive control (MPC)	Reduces the average queue length and waiting time	This method is only effective for a small road network
Connected vehicles environment	Global cordination of vehicles with safety and trajectory generation	High computation time
Cooperative adaptive cruise control	Traffic flow improves in conditions with high-traffic volume	Vehicle communication is restricted to longitudinal control only
Genetic Algorithm	Optimizes traffic flow to use altenative route with minimal computation time	Can not be applied to an isolated intersection
Job scheduling	Isolated intersection is considered as a single machine	Not suitable for multiple intersection
Automatic merge control	Safe vehicle maneuver at road intersections	Requires a large investment in road infrsatructure, not suitable for intersection control because of complex movement involved
Multi agents approach	ensure the driver's safety and increasing the travel efficiency	Can not handle multiple policy features simultaneously
Virtual platooning	Effective in a one-way intersection system	vehicle pass through intersection without stoping, and independent control of vehicles to follow the preceeding vehicle
Cooperative Vehicle Intersection Control	Avoid presence of any pair of conflicting vehicles at the same time and fix the acceleration	High computation time

traffic flows efficiency.[25]

2.3 Cooperative adaptive cruise

Using vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communications, cooperative adaptive cruise control (CACC) systems can safely drive vehicles with very short headway by forming platoons to improve traffic-flow capacity of a road. The concept of following a vehicle with a short gap in cooperative adaptive cruise control. (CACC) can be extended to offer a new intersection control paradigm, in which nearly conflicting vehicles from different approaches can cross the intersection keeping marginal gaps using intersection control unit which controls both the traffic lights for human driven vehicles and the sensors of the automated vehicle. Such an intersection control paradigm would unleash the full potential of intersection control unit in mostly eliminating stop delay, reducing travel time, and increasing the capacity of an intersection (efficiency).[52, 41, 38]

2.4 Vehicle Platooning

Connected vehicles environment provides a two-way wireless communication enabling vehicle-to-vehicle (V2V) and vehicle-to-infrastructure communications[26]. By using V2V communication, cooperative adaptive cruise control (CACC) systems can safely drive vehicles with very short headway by forming platoons to improve road traffic-flow capacity. [52, 41, 38]. The advanced capabilities of CAVs provide enormous opportunities to develop various innovative traffic ow control approaches ranging from cooperative adaptive cruise control (CACC), speed harmonization, signal control to mention but a few. With great potential to improve trac safety, efficiency, and environmental sustainability, intersection coordination scheme have obtained extensive research interests. [19, 10, 59, 49] [27, 17, 30, 55]. The concept of following a vehicle with a short gap in CACC can be extended to offer a new intersection control paradigm, in which nearly conflicting vehicles from different approaches can cross the intersection keeping marginal gaps without using any traffic signal. Such an intersection control paradigm would unleash the full potential of automated vehicles in mostly eliminating stop delay, reducing travel time, and increase the capacity of an intersection. However Omae et al.[38] proposed a virtual platooning method for automatic vehicle control at an intersection for passing through without stopping. In this case, vehicles on all lanes are considered on a virtual lane, and considering their interference at the intersection, they are independently controlled to safely follow the preceding vehicle in the platoon. The method is experimented at an intersection of one-way traffic using four electric vehicles equipped with automatic driving and V2V communication technologies

2.5 Automatic merge control approach

Raravi et al.[42] proposed an automatic merge control system for intelligent vehicles under a cooperative vehicle-infrastructure environment that ensures safe vehicle maneuvering at road intersections. By formulating an optimization problem with constraints to guarantee safety, the optimal maneuvers for merging vehicles were obtained by minimizing the driving time within an intersection for every vehicle coming from two conflicting approaches. Merge control application based on V2V communication under the concept of virtual vehicles that is used to map vehicles on one lane onto the other lane for ensuring safe distance criteria was a good contribution but not suitable for intersections since complex movements of vehicles to and from various lanes are involved [51]. According to[37] connected autonomous vehicles utilize communication systems to enhance performance and consequently improve transportation by enabling cooperative functionality, namely, cooperative sensing and cooperative manoeuvring.

2.6 Virtual Vehicle Mapping

According to Uno et al.[51] the merge control application based on V2V communication under the concept of virtual vehicles is used to map another vehicles on one lane to another for ensuring safe distance criteria. These merge control systems, however, are not suitable for intersections since complex movements of vehicles to and from various lanes are involved.

2.7 Autonomous intersection management(AIM)

Dresner and Stone [14] presented an idea of autonomous intersection management (AIM) as an alternative to the traditional traffic signal control mechanism. In AIM, vehicles and intersections are treated as autonomous agents in a multiagent system. The intersection is divided into a number of cells, and an intersection manager program coordinates the reservation requests of temporal cell occupancy's from every vehicle and offers right-of-way for each vehicle for ensuring safe crossing. However, this method does not coordinate the vehicles globally for their optimal flow and therefore stop delay cannot be avoided sometimes. Dresner and Stone [14] presented an idea of autonomous intersection management (AIM) as an alternative to the traditional traffic signal control mechanism. In AIM, vehicles and intersections being divided as a cell and are treated as autonomous agents in a mulltiagent system. The problem associated with this method is inability for a global coordination which cannot avoid stop delay. According to the work of [3] intersection control policy for human driven,semi-autonomous and autonomous vehicles divides the intersection into a grid of reservation tiles, whose notation can be generalized for rectangular and irregularly shaped intersections, when a vehicle approaches the intersection, the intersection manager uses the data in the reservation request sent by the vehicle regarding the time and velocity of arrival, vehicle size, etc. to simulate the intended journey across the intersection. At each simulated time step, the policy determines which reservation tiles will be occupied by the vehicle.It introduced a protocol called Semi-Autonomous Intersection Management, which allows vehicles with partially-autonomous features such as adaptive cruise control to enter an intersection from different directions simultaneously. By removing human factors from control loops of intersection, autonomous vehicles, with the help of advanced sensing devices, it can be safer and more reliable than human drivers. The AIM protocol exploits the fine control of autonomous vehicles to allow more vehicles simultaneously to cross an intersection thus effectively reducing the delay of vehicles by orders of magnitude compared to traffic signals[14, 16].

2.8 Cooperative Vehicle Intersection Control

Recently, a cooperative vehicle intersection control (CVIC) system has been proposed, it enables cooperation between automated vehicles and infrastructure for effective intersection operations [32]. The CVIC algorithm is based on minimizing the overlaps of trajectories of conflicting vehicles at the intersection. More specifically, this system simply tries to avoid the presence of any pair of conflicting vehicles at the intersection area at the same time. The trajectory of each vehicle is generated by fixing an acceleration rate from its current position to the end of the intersection, therefore, the natural dynamic behavior of a vehicle is ignored in the prediction horizon. Moreover, CVIC keeps the optimization problem simple without including any constraints for cross-collision avoidance, and minimization of the overlapping trajectories does not guarantee a feasible collision-free solution. Hence, an additional algorithm, in the form of priority rules for some lanes, is required to deal with the system failure resulting from infeasible solutions [26]. Current research direction towards innovative intersection management attempted to control vehicles without using traffic signals. Raravi et al.[42] proposed an automatic merge control system for intelligent vehicles under a cooperative vehicle-infrastructure environment that ensures safe vehicle maneuvering at road intersections.

The vehicle queue length during red cycle was used to control the green cycle in the same period for effective intersection utility [8, 1, 4, 56],. A method of detecting the length was proposed by taking the texture difference to separate vehicles from roadway as well as edge detection. This method was interesting but it does not function at real time which inadvertently effected the efficiency. Scott et al[33] investigated the implications for intersection capacity and level-of-service of providing occupants of automated and autonomously-operating cars with ride quality that is equivalent (in terms of maximum rates of longitudinal and lateral acceleration) to rail systems. Findings show that car passengers start experiencing discomfort at lower rates of acceleration than car drivers[31, 43, 5, 23]. It is therefore possible that occupants of an autonomously-operating vehicle may wish to instruct their vehicle to maneuver in a way that provides them greater ride comfort than if the vehicle-control algorithm simply mimicked human-driving-operation.

For fuel efficiency, several driving behaviors are automatically recorded by the driving simulator every 100 metres. Adding another time elapsed, allows real time cumulative fuel consumption to be computed and displayed to drivers.[57]. According to[53] an effective way to reduce fuel consumption in the short run is to reduce change in drivers behaviour, hence if drivers are prepared to change their driving habit, they can complete the same journey within similar travel time and significantly use less fuel. Normative model which back calculate the minimal fuel consumption for manoeuvring carried out.

The innovative method above will differentiate our approach from coordination algorithms or scheme and demonstrate our unique contribution to knowledge as well. The concept of following a vehicle with a short gap in CACC can be extended to offer a new intersection control paradigm, in which nearly conflicting vehicles from different approaches can cross the intersection keeping marginal gaps using traffic signal. Such an intersection control paradigm would eliminate stop delay, reducing travel time, and increasing intersection capacity and also address the issue of steady speed for human driven vehicle. The novelty of the proposed scheme is the global coordination, by considering the states of all vehicles together in the ICU, based on avoidance of their cross-collision risks at the intersection. The scheme efficiently utilizes the intersection area by preventing each pair of conflicting vehicles from approaching their cross-collision point (CCP)at the same time, instead of reserving the whole intersection area for the conflicting vehicles successively. Moreover, the introduction of relevant constraints ensures the scheme is free from any collisions and enables to manage turning movements of the vehicles under a safe velocity limit. Turning vehicles sometimes need special treatment so that multiple vehicles slowly and closely cross the intersection, which is realized in the VICS [25]. The method of coordinating scheme which directs vehicular traffic proximate to a potential travel-priority conflict zone involves communicating with the dynamic traffic control system located on-board autonomous vehicle's potential travel-priority conflict zone so as to establish a dynamic traffic control plan for avoiding a travel-priority conflict such as.

- Delay
- Capacity Utilization
- Efficiency
- Health and Safety

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