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LITERATURE SURVEY ON CO-OPERATIVE ADAPTIVE CRUISE CONTROL SYSTEM

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Abstract: Autonomous vehicles have been increasingly contributing to a better way of transportation by using Vehicle to Vehicle communication technology, in which the information is collected from different kinds of sensors that are incorporated in the vehicles. This paper is a review on different types of technologies which are a part of autonomous systems. The innovative solutions proposed by researchers and industries in the recent years have been elaborately reviewed in this paper. It has been greatly observed that the major research arenas focusing on autonomous systems can be categorized under Cruise control, Adaptive Cruise Control, Vehicle to Vehicle or Vehicle to Roadside Communication, vehicular delay tolerant networks, Co-operative Cruise control, smart drive assistance through networking.

Keywords: Adaptive Cruise Control, Intelligent Transportation System, Platooning, Self Driving Vehicles, Vehicular Delay Tolerant Network.

I. Literature Review

[1] An autonomous car is a vehicle that is capable of sensing its environment and navigating without human input. It is also called as a driverless car. Autonomous cars can detect surroundings using a variety of techniques such as radar, lidar, GPS, odometry, and computer vision. The two most popular autonomous driving systems that are currently in production are the Cruise Control and the Adaptive Cruise Control systems. By using Cruise Control system, the vehicle is able to travel at a set speed. This system is composed of two level controllers where the high level controller translates the reference speed to acceleration command and the low level controller translates the latter into throttle or brake commands. [2]Adaptive Cruise Control (ACC) system provides an automotive feature that allows a vehicle's cruise control system to adapt the vehicle's speed to the traffic environment, hence contributing to reduced traffic accidents, thereby improving traffic flow. The ACC reduces the driving burden on the driver by controlling the acceleration and deceleration of the vehicle, maintaining a set speed to avoid crash, leading to an improvement in driving stability. California Partners for Advanced Transit and Highways (PATH) have achieved improved vehicle-following performance, using vehicle-vehicle cooperation in eight fully automated cars using wireless communication. The Safe Road Trains for the Environment (SARTRE) European Union project has developed virtual trains of vehicles in which a leading vehicle with a professional driver takes responsibility for each platoon. The extension of the commercially available adaptive cruise control (ACC) system toward the cooperative ACC (CACC) system leads to a high potential to improve traffic flow capacity and smoothness, reducing congestion on highways. The CACC system uses wireless communication as a result of which potential risk situations can be detected earlier, to help avoid crashes and in addition a more extensive and reliable information about other vehicles' motions is gathered to improve vehicle control performance. In addition, there are various challenges in an ACC system which must be addressed in the near future. One of the most important issues observed among drivers in ACC system is their inability to adapt to changing driving habit among drivers. [3] As driving habits change among drivers and over time in the ACC system, an intelligent ACC system should adapt to different driving habits. Otherwise a driver would intervene even in situations that ACC is able to manage. The existing ACC systems takes into account the common driving habit among drivers but for better results efforts, must be taken to incorporate the individual driving habit in ACC systems. Reinforcement learning method, such as supervised adaptive dynamic programming and supervised reinforcement learning has been adopted to address such problem. Moon categorized driving situation into safe, warning and dangerous modes using warning index and the time-to-collision, then the different control strategy was adopted depending on these modes and hence a same performance as manual-driving was obtained. Model predictive control was used to design the ACC system in with the objectives of comfort, fuel-economy, safety and car-following. A novel adaptive optimal control approach based on Q-function has been proposed to address the problem as the driving habits change

among drivers and over time in the adaptive cruise control system. Research advances incorporating V2V communication, in CACC systems resolves the major issues involved in ACC systems. By introducing V2V communications in CACC systems, the vehicle gets information not only from its preceding vehicle—as occurs in ACC—but also from the vehicles in front of the preceding one. [4]The current scenario where driver error is the most common cause of traffic accidents can be improvised greatly using SDV technology. SDV cars utilize computational algorithms, sensors, and communication devices to automatically navigate a variety of environments without human drivers. SDV technology has the potential to radically transform our transport system, improving our living environment. The application of self-driving technology to public transport will not only bring in new forms of shared mobility, but will also address the constraints faced in land and manpower. Google kick-started its own self-driving car project in 2008 and it has been rumbling on ever since first with modified Toyota Prius and then with customised Lexus SUV. In mid-October 2015, Tesla motors announced that all of its new cars would be outfitted with equipment that would allow them to drive on their own, confirming that all TESLA vehicles will have the hardware needed for full self-driving capability at a safety level substantially greater than that of a human driver. Various perspectives from social justice and ethics show that SDVs lead to profound consequences for users and societies which must be considered greatly. To address these challenges, a framework for a more ethical design practice for SDV systems must be addressed, steering current engineering practices on SDV technologies away from a narrow, technical perspective, taking into account social concerns and ethical investigations. [5] Road weather events increase both travel time and crash risk, which results in a surface transportation system with compromised reliability. Crash frequencies increase significantly during inclement road weather conditions, although traffic demand is far lower than in normal conditions. ITS infrastructures are advanced applications, most widely used to inform motorists about current and future traffic conditions, which help travellers to make informed decisions in route selection and other pre-trip planning. ITS aims to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and smarter use of transport networks. The U.K. has installed a set of road weather radars to collect real-time radar imagery to develop a maintenance program and reported improvement in maintenance planning. Sweden has been piloting the use of floating car sensor data to combine with RWIS data for winter maintenance planning. France has been utilizing an automatic data fusing framework i.e., “Optima,” which utilizes several road weather data sources to update road weather conditions every 5 min, which has proven useful for real-time road weather management. The challenge to provide reliable road weather information to the users remains, which is currently hindered by the two factor namely, spatial heterogeneity in the surface transportation network and weather pattern as well as the scarcity of monitoring systems to collect road weather information. Other challenges include, predicting the extreme precipitation events, translating available extreme information to reduce the transportation infrastructure damage risk (for example, urban and highway flooding and landslides affecting traffic movements) and determining the role of Global Climate Models (GCMs) in ITS infrastructure development. Further study in the field of automated vehicles leads to the analysis of vehicular platooning concept. A group of coordinated vehicles is called a platoon. [6] Automated and coordinated vehicles’ driving referred as platooning is a very important feature in this field due to the multi-body control complexity and the presence of unreliable, time-varying wireless Inter-Vehicular Communication (IVC). Coordinated driving can improve driving experience by relieving humans from some driving duties and at the same time, by letting an automated system control the vehicle, improving safety. Moreover, by reducing inter-vehicle distances, cooperative driving can improve traffic flow and reduce fuel consumption. As such goals are not achievable using standard sensor-based Adaptive Cruise Control (ACC), the community started considering Cooperative Adaptive Cruise Control (CACC). This signifies the importance of platooning in CACC systems. [7] Vehicle-to-Vehicle wireless communication protocols points out the need for Vehicular Collision Warning Communication (VCWC) protocol to improve highway traffic safety. Emerging wireless technologies for vehicle-to-vehicle (V2V) and vehicle to-roadside (V2R) communications such as DSRC are promising to dramatically reduce the number of fatal roadway accidents by providing early warnings. A Joint V2V/V2R (R2V) communication protocol for cooperatively collision avoiding, improves the communication reliability. Previous research work with regard to V2V communication has focused on three aspects: Medium access control, Message forwarding, and Group management. Briefly, MAC protocols coordinate channel access among different vehicles; multi-hop forwarding mechanisms extend the reachable region for warning messages; and group management protocols define the group of vehicles that share a common interest. A vehicle can become an abnormal vehicle (AV) due to its own mechanical failure or due to unexpected road hazards. In general, the abnormal behaviour of a vehicle can be detected using various sensors within the vehicle. A vehicle controller can automatically monitor the vehicle dynamics and activate the collision warning communication module when it enters an abnormal state. ACC based intelligent systems with on-board perception/detection devices have contributed greatly to improving road safety. Such types of significant developments have also been achieved in Advanced Driver Assistance System (ADAS). [8]Advanced driver assistance systems (ADASs), are automotive systems designed to assist in all aspects of driving, including safety, drivability, and fuel economy. Examples of ADA systems are various forms of cruise control, lane-keeping systems, and collision-warning systems. The implementation of ADAS may lead to a fatality decrease of 40%. Innovative Advanced Driver Assistance Systems help drivers stay on top of things, helping them arrive safe and relaxed. The CarTALK 2000 project focuses on developing cooperative driver-assistance systems, which are based upon mobile, inter vehicle communication. The traffic impacts of two applications, which are basic warning function and early braking, were assessed using MIXIC model. The MIXIC model is a stochastic simulation model MIXIC which takes into account all the required considerations for assessing the impacts on traffic performance, traffic safety, exhaust-gas emission, and noise emission. [9] Vehicle platoons are chains of automatic cars that are supposed to travel with a tight spacing in a highway lane. They are expected to increase the safety and capacity of highways. In the absence of inter-vehicular communication, the only available information is the one measured by the onboard sensors, especially the inter-vehicular distances. It turns out that certain properties of such platoons need not scale well for a growing number of vehicles. [10] A requirement of any CACC system is that it must be able to support the merging of vehicles inside an existing platoon. Vehicles may for instance simply wish to join a platoon, or are forced to do so at a road narrowing or at a merging junction. A new geo-casting concept to target vehicles based on where they will be in the direct future, instead of their current position. This concept is referred as constrained geo-cast. This may be useful in situations where vehicles have interdependencies based on (future) manoeuvres when a vehicle inside a platoon receives a request from another vehicle to join the platoon it will create a so-called merging gap by gradually decreasing its speed, thereby increasing the headway to its preceding vehicle. When the merging gap is large enough the merging vehicle aligns with it and joins the platoon. Afterwards normal CACC operation is resumed. We require a communication system that is able to warn any vehicle inside a platoon in advance, using indirect multi-hop communication that it needs to create a merging gap for a merging vehicle at a junction. (Abiding) geocast is a form of routing in which messages are routed through a network based on spatiotemporal constraints. We believe that this may prove a valid geocast approach for types of intelligent traffic systems that wish to target approaching vehicles, e.g., warning applications or traffic information applications. Leading European projects in the field of vehicular networking include COMeSafety2, SAFESPOT3, GeoNET4 and CVIS5. We use COMeSafety's European ITS VANET Protocol (EIVP)as network level protocol, and based our geocast protocol on SAFESPOT's positioning interface. Geobroadcast (or geocast), supports the dissemination of information in a larger geographical area.The sender of the information defines the geographical area where the data message should be disseminated and attaches it to the message. Information is sent once. In contrast, abiding geocast is a dissemination approach where the information is geocasted to all nodes that are inside a destination region within a certain period of time.Our constrained geocast protocol is therefore also constrained to the use of these beacons, although their timing may be altered. The goal of our CACC system is to have vehicles drive in platoon-wise fashion, with little room in between individual vehicles, such an approach may cause situations where merging vehicles will not be able to find a gap to merge in. More important even, since we assume that our system must work in an environment where vehicles are a mix of automated and non-automated vehicles, our system needs to be able to cope with non-automated vehicles. Later on we may add functionality, so that when the merging vehicle is similarly automated its speed may also be controlled. [11] The most important parameters that drivers must regulate during free flow, rush hour, and heavy traffic conditions particularly in highways are: (1) the speed of their vehicle and (2) the time-headway to the preceding vehicle. Rear-end collision is a major type of car accident, to avoid rear-end collisions, it is important to drive at a safe speed and maintain a sufficient time-headway to the vehicle ahead. Drivers following with short time-headways tend to be better at programming and executing the intensity of braking to required levels. Lee (1976) found that safe timeheadway depends on speed, braking capacity, and visibility, and in general should be Larger than 2 s. Treiterer & Nemeth (1970) found that nearly 50% of headways in interstate traffic were between 1 and 2 s, and over 20% were below 1 s. Von Buseck, Evans, Schmidt & Wasielewski (1980) reported a median time-headway of approximately 1.4 s in urban interstate traffic. Van Winsum & Heino (1996) found that when drivers' speed was within the range of 40-70 mph, their preferred time-headway was kept at 1 s. The typical range of time-headways observed (1-2s) matches the range of reaction times observed in emergency braking. This match maintaining a time-headway that matches one's response capability is just adequate for avoiding collisions, as long as a driver is attentive and alert and the vehicle has good braking. Maintaining a 1-2 s time-headway does not eliminate collisions. Drivers look away from the forward environment for typically 1-1.5 s per glance in order to conduct in-vehicle tasks or check rear view mirrors (again, generally but not always safe Ayres, Donelson, Brown, Bjelajac & Van Selow, 1996) such a glance at the wrong time can eliminate the safety margin represented by the time-headway. Drivers are most likely respond adequately if they need to intervene or take control. Drivers are most likely to accept time-headways of 1-2 s which will likely make drivers feel uncomfortable because they sense that they cannot respond adequately if they need to intervene or take control. On the other hand, imposition of time-headways substantially longer than 2 s will seem excessive to most drivers, even though highway safety might be improved. Among fixed-distance approaches such as the predecessor following, an unpleasant phenomenon known as string instability can occur. [12] String Stability of Interconnected Vehicles implies a study of Cooperative Adaptive Cruise Control (CACC) system which regulates inter-vehicle distances in a vehicle string by utilizing the information exchange between vehicles through wireless communication and local sensor measurements. String stability enables vehicles to be interconnected by another vehicle following control law and a constant time headway spacing policy. This analysis technique can be used to investigate tradeoffs between CACC performance (string stability) and network specifications such as delays, which are essential in the multidisciplinary design of CACC controllers. The propagation of disturbances through the interconnected vehicle string is inspected by using string stability. String stability ensures that automated vehicles travelling in platoons exhibit stability both individually and as a group. String instability may produce a small disturbance at the beginning of the string which grows without bound while propagating through the string disturbing the complete structure of the vehicular platoon. Some research has focused on making use of underlying interconnection structures to derive scalable system theoretic properties for this type of platoon systems. More recently, proof-of-concept demonstrations with CACC vehicles have been performed with homogeneous vehicle strings and also with heterogeneous vehicle strings in a multivendor setting. Networked Control System (NCS) based CACC model was developed and experimentally verified. The analysis framework for string stability was successfully performed in a Lelystad test with two CACC-equipped prototype vehicles. [13] From a research perspective, Vehicular Delay-Tolerant Networks (VDTNs) serve as a good starting point for interested researchers, which have been receiving increasing attention in recent years. Vehicular Delay-Tolerant Networks (VDTNs) are networks where vehicles communicate with each other in order to disseminate data using data bundles as a data unit. Vehicular networks are spontaneous self- organized networks, whereby vehicles equipped with short to medium- range wireless communication, persistent storage, and processing capabilities that cooperate with each other to enable communication with other vehicles or road side infrastructure equipment. Vehicular communication can be of great use in enhancing the efficiency of the transportation systems. The goal is to improve the traffic flow and road capacity through the use of applications and services such as traffic condition monitoring platooning, cooperative notification system, vehicle tracking, lane-changing assistance, freeway management, road congestion prevention, cooperative driving and toll collection. Vehicular networks can also collect and relay data gathered by a wireless sensor network such as weather conditions (e.g. temperature, humidity, rain fall, wind) pollution measurements (e.g. smoke, visibility, noise) road surface conditions and construction zones. Communication among vehicles and between vehicles and road side infrastructure using wireless technology has a large potential for enabling a plethora of applications and services, ranging from time- critical applications to delay- tolerant applications. These applications can be classified as: road safety, traffic optimization, commercial, entertainment, rural connectivity and disaster scenario connectivity. In order to harness the advantages of vehicular networks, a number of technical challenges need to be overcome before these networks can be widely deployed. It has been observed that difficult communication problems arise due to highly dynamic network topology and short contact durations caused by the mobility and speed of vehicles. Limited transmission range, radio obstacles due to physical factors (e.g. buildings, tunnels, terrain and vegetation) and interferences (e.g. high congestion channels caused by high density of nodes) can cause disruption, intermittent connectivity and significant loss rates. Furthermore, vehicular networks may have large node density variations due to location and time (e.g. dense in a traffic jam, sparse in suburban traffic and extremely sparse in rural areas). These factors make vehicular networks susceptible to frequent fragmentation and often lacking continuous end- to-end connectivity, which renders data dissemination and routing a challenging task. [14] In addition to VDTN there have been a lot of researches on development of driving assist systems. The major focus of the undergoing researches are on ACC, collision warning and collision avoidance systems and their impact on driver’s comfort, safety and traffic flow. Automated Highway System (AHS) is unlikely to materialize in near future but vehicle based assist systems have fewer barriers and hence, has attracted special attention and reached the production line. Collision warning and avoidance systems have the added complexity that they should be able to recognize a hazardous situation and communicate it to the drive-in Europe, the major research was under PROMETHEUS program funded by European automakers and governments of the European Union. In the United States, the PATH program founded by California Department of Transportation and Institute of Transportation Studies of the University of California at Berkeley sponsored major fundamental research projects in advanced vehicle and highway systems. In Japan the idea was to substitute a group of man-made driving decisions and actions with more systematic and precise machine tasks to achieve regulated traffic flow and, therefore, reach safer highways with higher capacities. Moreover such researches on driver assist systems for ACC, collision warning and avoidance systems provide a convenient way of evaluation of the recent advances in the field. [15] Cooperative Adaptive Cruise Control (CACC) is essentially a vehicle-following control system that automatically accelerates and decelerates so as to keep a desired distance to the preceding vehicle. CACC is vulnerable to unreliable wireless communication due to high latency or packet loss. CACC is vulnerable to communication impairments such as packet loss, in which case it would effectively degrade to conventional Adaptive Cruise Control (ACC), which requires significantly larger time headway, thereby increasing the minimal inter-vehicle distance needed for string-stable behaviour. The minimum string-stable time headway increases from 0.25 s to more than 3 s. It is, therefore, important to have an alternative control technique that exhibits string-stable behaviour for a less dramatic increase in time headway, which comes into action when a failure in the wireless communication is detected. Therefore, a control strategy for graceful degradation of one vehicle look-ahead CACC is required to partially maintain the string stability properties of CACC. A fallback strategy has been identified to gracefully degrade functionality of a one-vehicle look ahead CACC, based on estimating the preceding vehicle's acceleration using the available data from an onboard sensor. This estimated acceleration can be used as an alternative to the desired acceleration transmitted through wireless communication for this type of CACC. It is shown through simulations and experiments that the proposed strategy results in a noticeable improvement of string stability characteristics, when compared to the situation in which ACC is used as a fallback scenario.

II. Conclusion

This paper is a collective study of all the major concepts involved in automated driving. It highlights significant features of such systems and signifies their importance in enhancing traffic safety. The paper also discusses the challenges of such systems providing research based solutions to such limitations.

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