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The Application Study of the Assisted-Driving System Based on Internet of Things System

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Abstract: *In view of the instability and high-risked motor vehicle collision, this work proposes an Assisted Driving System (ADS) based on Internet of Things (IoT) concepts to prevent traffic accident. In detail, ADS utilizes Automated Emergency Braking (AEB) and embedded actuators in the steering wheel to control the vehicle in an emergency situation. AEB consists of four different subsystems that allow the vehicle to recognize potential collision and need to full-stop in interaction with pedestrian, biker, another vehicle, and infrastructure. Pedestrians and bikers need an application or Simplified System Device (SSD) to receive feedback from the interaction. Radar sensors, front-camera, RFID sensor and Speedometer also allow the ADS to operate on a single-vehicle circumstances. It is believed that the proposed system of this work has great application prospects.*

Keywords: *Internet of Things (IoT), Assisted Driving System, Collision Avoiding, Automated Emergency Braking*

1. Introduction

According to "Global status report on road safety 2018" published by WHO, more than 38,000 people die every year in crashes on U.S. roadways. The U.S. traffic fatality rate is 12.4 deaths per 100,000 inhabitants. An additional 4.4 million are injured seriously enough to require medical attention. [1] In a report published by NHTSA, the author noted "in 2002, motor vehicle traffic crashes were the leading cause of death for every age 3 through 33." [2] The driver's reaction times for accident vary greatly with situation and from person to person between about 0.7 to 3 seconds or more. Although the technology of autonomous vehicle like Google's self-driving car is well-developed, it still takes decades for autonomous vehicle to replace normal cars in widespread use. In that case, the assisted driving system is developed to guarantee the safety in driving and provide some assistance for drivers to prevent the potential collision.

In ADS, the IoT system processes the feedback from sensors (LIDAR, vehicle speed sensors and GPS), collects and processes data, and sends the instructions to actuators (steering, acceleration, and braking). This means that the system could make command to change the speed or stop the steering wheel from turning to a wrong direction. In ADS, obstacle avoidance and prediction model for collision are also equipped to guarantee the safety for driving, and the system also takes infrastructure, pedestrians or bikes and vehicle into consideration.

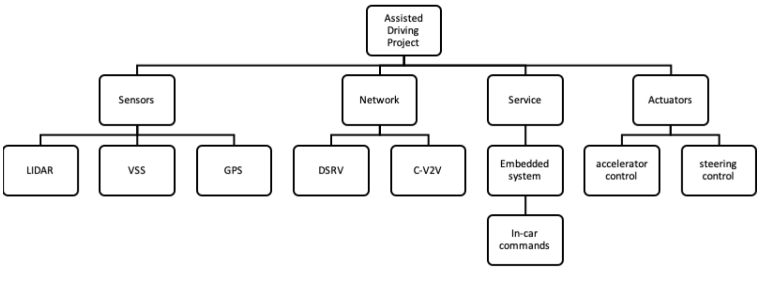

Figure 1. Layer Structure

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2. System Structure

The whole ADS is divided into four subsystems for a more accurate prediction for accidents. A 360° view camera is equipped on the top of the car to distinguish the infrastructure, non-vehicle and vehicle into four scenarios, thereby providing a broader picture of the external traffic conditions [3]. Sensors are equipped in order to collect data like speed, distance between vehicle and object, signals in traffic. Cameras identify objects like other cars, pedestrians, bikes, traffic signs, road markings, bridges, and guardrails, then the AEB (Auto Emergency Braking) system select a certain subsystem for the further operation. After the data was send to the central controller, the actuators receive the command for the embedded system. By equipping cars with the controller in actuators, vehicles are capable of maintaining a steady pace and preventing the potential collisions.

3. Single Vehicle

‘‘Global status report on road safety 2015’’ by the world health organization indicates that over 3400 people die on the world’s roads every day, and the total number of road traffic deaths has plateaued at 1.25 million per year. Under the scenario of single vehicle, the system carries fully integrated controllers, sensors and actuators that could assist driver while facing an emergency situation. The basic function and the system structure will be presented in the following description.

3.1 Structure

Although it seems that the ADS haves a normal linear progression while it working, these systems are in parallel and simultaneously. There are sensor system, embedded system and actuator system in ADS for the basic function—collision avoiding as they are showed in figure 2. The sensors, central controller and actuators are all operating at the same time and the whole system will be updated and formulated during the driving.

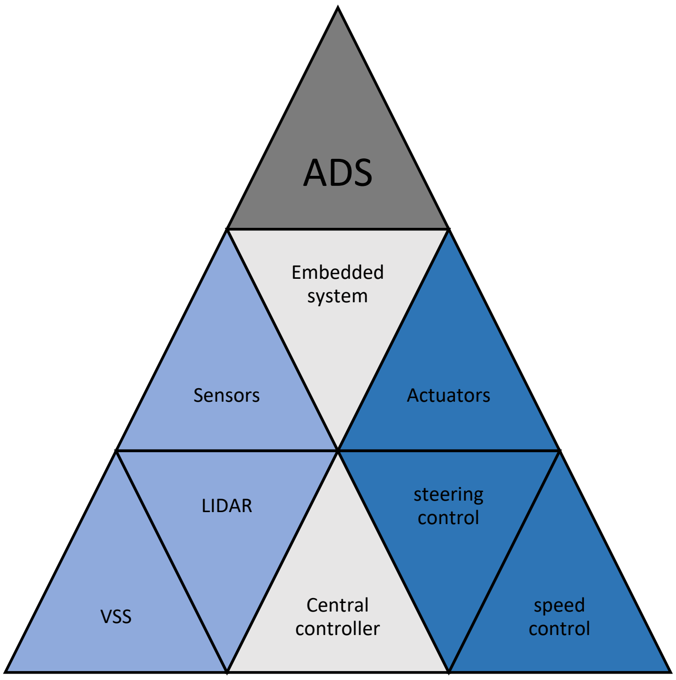

Figure 2. Single-Vehicle Scenario Structure

3.2 Sensors

3.2.1 LIDAR

LIDAR is a device combined laser with radar, which provides the view of the surrounding installed atop of a vehicle. It helping the system detect the distance of other objects by sending thousands of lasers pulses every second. These pulses collide onto objects around and reflect back to the vehicle, at the same time, central controller collects and translates these data into a 3D representation inside the embedded

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system. The 3D representation is created by calculating the speed of light and the time they reflected back in each point to identified vehicle's position with surrounding objects. The special characteristics make the LIDAR provides the accurate distances even in a dark environment or bad weather like rainy and foggy.

3.2.2 Vehicle speed sensor (VSS)

Detecting the speed of cars is one of the important sections of the assisted driving system. Vehicle speed sensor (VSS) is a type of tachometer that could measure the speed through the wheel's rotation. It is a better choice for the assisted driving system as a sender device among the image-based and radar-based measure methods for monitoring the vehicle's speed [4]. VSS is an insertable device in the ADS, the speed is directly transmitted to the central controller processing unit and combined with the location information for the further analyze.

3.2.3 Global Positioning System (GPS)

Emerging technologies based on Global Positioning System (GPS) enable us to track vehicle trajectories and collect real-time data across entire road networks. By using satellites, GPS transmit the data about locations for vehicles. In ADS, GPS plays the role of "traffic director" who collect the location date and then update information in the embedded system. All the motion of the vehicle would be record by GPS while analyzing the data that collected from each vehicle's transport research and control. Moreover, GPS is already equipped in most of the cars for navigation so that ADS could connect to GPS and derive position of the vehicle from it at low cost. The safety and management are also guaranteed by Global System for Mobile Communications (GSM) which provide network communication function and the GPS positioning could be sent to the third party in ADS.

3.3 Central Controller

With the help of sensors, the embedded system receives the vehicles' travelling data and the information of surrounding objects. In the controller, analyses were conducted on the raw data. The embedded system analyzes and processes these detective data, constitute and adjust the relevant strategy and then make a response command on actuators. Systems are working in parallel and simultaneous with each other without latency between the elements' updating and communications. Moreover, Adarsh Pal Singh and Sachin Chaudhari presented a machine learning-based data transmission reduction scheme for application-specific IoT networks [5], which could also be used in ADS to incorporate machine learning in constrained sensor nodes to reduce data transmissions.

In ADS, central controller could determine a smoothly speed and direction for vehicles to avoid collisions and potential accidents. It serves as a data base and data translator for the speed, surrounded objects and location to organize and manage the whole system. The model and algorithm are preloaded inside for future use as well as the command the system will make like speed-control or turning into another direction.

3.4 Actuators

Actuator system is the control mechanism in the ADS. For accelerator control, the actuator system combined electric actuator (controls the accelerator pedal) with a parallel linkage (controls the brake pedal). The linkage provides an opposite movement to the pedal so that the brake pedal could be controlled and the speed could be limited within a certain range. In steering control, any deviations could be detected by sensors and the feedback from embedded system will control the difference caused by drivers' miss operation. Plus, the servomotor will help by changing from open-loop into closed-loop in order to control the front steering wheel.

4. Vehicle to Infrastructure

4.1 Traffic Light

The interaction between the vehicle and the traffic light requires the RFID tag and reader to be embedded both in the traffic light and the vehicle respectively. Each traffic light equips an active RFID tags that is placed inside the traffic light control unit. Because each unit can last 3-5 years with the battery, it doesn't require costly maintenance. The range of an active RFID tag is about 100 meters which is similar to the GPS forewarning for an intersection.

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To enhance drivers' compliance with the STOP sign control and awareness of a coming intersection, previous research suggested some simple and low-cost treatments, such as increasing the visibility of STOP signs and adding pavement markings [6].The RFID tags embedded in the traffic light is programmed to send a signal when the light is red and vehicle cannot pass and stops when the light turns green which allows the vehicle to pass. The RFID signal is read by the RFID reader embedded in the vehicle. Once the RFID reader receives the signal, it informs the central processing system which can contact the actuators on brake to decelerate. The range of an active RFID tag gives the vehicle buffer to enter a full-stop.

To compensate for rural traffic infrastructures, the ADS V2I system also consist of a front camera, a processing application, and actuators on the brake. The front camera which is embedded in the car grill captures image which is connected to the local central processing computer inside the vehicle. The artificially trained image-identifier system can recognize the image of a traffic light or a stop sign and gauge is rough distance if one is present. If stop signs or red lights are present, the vehicle automated braking system would override the driver and decelerate.

4.2 Stop Sign

ADS system interacts with the stop sign via the front camera. Since stop sign is easy to capture by an artificially trained algorithm and is standardized, ADS system uses the front camera to recognize the stop sign and transmit the data to central processing. The processing system is able to then determine the distance of the stop sign based on the size of it and commands the actuators on the brake to come to a full stop.

It’s important to note that the vehicle to traffic infrastructure provides a base for the complex algorithm to prevent accident. The data provided by the interaction between vehicle and traffic infrastructure should be combined with V2V data and radar data to depict a complete picture of the traffic condition. The central system then calculates the risk of the situation and commands the actuator on the brake to act accordingly.

4.3 Roadworks

It’s common to have roadworks which blocks a lane in traffic. ADS system tackles this problem with the C-V2V network and radar. The system is able to obtain the roadwork information from the cloud using cellular network, assuming the information is uploaded timely. Leveraging the vehicle’s GPS, the central processing system is able to pin the location of roadworks on the local map. The system forewarns the driver when the driver is approaching. If the driver is unaware and didn’t see the road blockage, the vehicle then uses radar to determine the distance to the cones and commands the actuator on the steering wheel to change the steering angle to prevent collision with the road blocks.

4.4 Urban Infrastructure

Occasionally, the urban infrastructures, such as missing well cover, jeopardizes driver’s safety. However, it’s not cost-effective to install an ARA laser for every vehicle; and companies such as Road scanners collect data for road conditions. ADS system leverage C-V2V network to obtain the data relating to potential urban road dangers from the cloud and pin the location on the local map. Therefore, when drivers approach a potentially dangerous infrastructure, the central system can react by applying the brake because the locations are pinned on local map. The central system takes negligible propagation time to calculate and to retrieve data from the local map.

4.5 Extreme weathers

Extreme weathers can also jeopardize drivers’ safety. ADS system uses C-V2V network to retrieve weather data from the cloud and remind the driver before he/she starts the engine about the extreme weather condition that may endanger the driver.

If the driver chooses to proceed, the vehicle can then retrieve data about the potentially dangerous road segments and pin them on the local map. Similar to the process of urban infrastructures, the central system prevents the vehicle from approaching potentially dangerous areas. Moreover, to compensate the untimeliness and inaccuracy of the cloud data, there is many hydro-sensors that are embedded in the chassis of the vehicle to detect the presence of water in vehicle mechanics. With the data, the central

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processing system can then determine the risk of water making an engine failure. When the risk is high, it's advised that driver to leave the vehicle and the vehicle is disabled.

5. Vehicle to Non-Vehicle

Although vehicles that have equipped with the system device are connected to and recorded by cloud and the connection maintains its high-efficiency nature since the system is using DSRC+C-V2V network, it may not be fast enough for some subsystems. Under the scenario of vehicle to non-vehicle, Pedestrians and bikes are considered two main factors that the system needs to have interaction with. The radar distance sensors, which are embedded inside the car, are frequently measuring their distances to the pedestrians by transmitting and receiving high frequency radio waves (microwaves). Pedestrians, on the other hand, are measured the distances to all surrounding moving cars through a software installed in their phone. Normal GPS location service embedded in the mobile devices, however, is abandoned in this situation since the location service is not capable of measuring the precise distance length in meters. Unlike the discussions in previous scenarios, the vehicle to pedestrian sub-system is largely based on a non-cloud service system or a local service system since the cloud service would be redundant and slow. Therefore, the direct interaction between the system device in the car and the software in people's mobile phones through frequency radio waves is faster and has lower latency.

Similar to the vehicle to pedestrian scenario, the interaction between cars and bikes on the road also requires the radar distance measuring technology. The interaction between bikes and cars should be more intense to some extent as there are more blind spots when people are riding bikes. Therefore, a simplified system device (SSD) with radar measure sensors is required to be installed on the bike. The SSD does not contains high dimensional detection service and it has relatively lower range measuring distance compared to the system device on the vehicle.

5.1 Vehicle to Pedestrians

The radar method of measuring distance requires radar distance sensors to be embedded inside the vehicle. It may be assumed that several factors influence the decision of the pedestrian: pedestrian-related factors such as mobility, assertiveness and possibly the context (being in a hurry or not, as well as location on the road), but also vehicle-related factors, both behavioral (distance, speed and acceleration) and appearance [7]. Since the vehicle to pedestrian subsystem does not use cloud service, a direct connection between the car radar distance sensor and the high frequency radio waves from the mobile app is required. Depending on the current vehicle speed, when a car is approaching a pedestrian within a threshold range, the radar distance sensor is instantly detecting the distance from the car to the person and updating the value of distance every half second to ensure there is enough time for the car to slow down. The mobile app on the pedestrian's phone also sends a strong alert bypassing all other app on the phone so that the showing of the alert would not be affected by any other factors. For example, the alert shows on the screen and sounds the phone even if the mobile phone of the pedestrian is set to mute mode.

There are two extreme cases. If the maximum braking distance sensor detects that the value send back from the radar distance sensor is reaching the threshold value of the maximum braking distance sensor based on the current vehicle speed, emergency brake responder is then triggered within ½ second and thus the brake pedal is forced to be pressed by the system. Another situation would be the worst-case scenario. If the system detects that the current vehicle speed has exceeded the car required braking distance threshold, the steering wheel responder is then triggered and forces the steering wheel to turn the vehicle to the direction which the pedestrian cannot be hit.

During the nighttime, the system utilized the Night Vision system, which was developed by Honda in 2004, to highlight the pedestrian in front of the vehicle by alerting the driver with an audible chime and visually display them via HUD. Besides the Night Vision system, the collision avoidance functionality works the same as it works during daytime.

5.2 Vehicle to Bike

There were 857 bicyclists killed in traffic crashes in the United States in 2018 [8]. Therefore, vehicle to bike subsystem requires a more intense design. A simplified system device (SSD), which has less sensors than the car embedded system device, is designed for non-motor vehicles such as bike to equip. SSD is equipped with radar distance sensors which detects four directions: front, back, left, and right. Namely, the "assisted" functionality is not implemented on the SSD. The SSD is merely used for warning

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the vehicle driver and the biker since the radar distance sensor can both transmit and receive high frequency radio waves.

When a car is approaching a bike, the radar distance sensor, which detects the incoming car, transmits an alert signal to the SSD processing center so that the alert sound on the bike can be triggered. The alert sound is modified to be the precise direction information about the incoming car. For example, if a vehicle is driving towards a bike from the left, the radar distance sensor on the left receives the system device microwave signal from the car's radar distance sensors and then sends the alert signal to the SSD processing center to complete the alert information processing within ½ second. The SSD processing center output the processed signal to the alert speaker on the bike to output the word "left" in order to warn the biker about the incoming car from the left. The whole detection and warning process take 1 second in total to ensure the efficiency of the SSD warning system.

On the vehicle level, however, the system device embedded in the car keeps all its original functionalities. When a car is moving towards a bike, the LIDAR sensors in the car read the incoming high frequency radio waves from the bike to detect and classify the thing in the front [9]. Then, if the maximum braking distance sensor detects that the speed of the car is reaching the threshold set, the autonomous braking system in the car is triggered. On the other hand, if the speed of the cars exceeds the set threshold, the steering wheel responder is then triggered and forces the steering wheel to turn the vehicle to the direction which the bike cannot be hit. In general, the detection principle of the vehicle in the vehicle to bike subsystem is highly similar to the car detection principle in the vehicle to pedestrian subsystem. During the nighttime, the system utilizes the same Night Vision system technology, as introduced in 3.1, to detect bikes.

6. Vehicle to Vehicle

Under the scenario of vehicle to vehicle, the vital factor would be that the behaviors of vehicles in different situations should be counted in. In order to detect the behaviors accurately, several sensors are used to transfer the relevant and real-time data to a computational processer which, through the data would clearly quantify the behaviors of vehicles such as velocity, direction, and location. Additionally, for some extreme scenarios, namely under villainous weather or in the tunnel, the signals might be unstable to fulfill the goal. Therefore, establishing the reliable connection and communication among vehicles is also critical. Based on the communication system, the imbedded computational processor in any individual vehicle could make some confinement or recommendations to a driver automatically, after analyzing the data.

6.1 Detection and Communication

Although it is unreal that only two single vehicles are interacting with each other, the vehicle to vehicle system could be described as various combinations of the interaction between two vehicles. Examining such an interaction is one reasonable simplification, since the computational processor would analyze all the data collected, and which will be further discussed with details in the following.

The distance between two vehicles is not a simple equivalent of the shortest distance. A distance detection system is needed and the distance should be labeled and analyzed in a plane coordinate system. Moreover, wireless communication service is employed to make connection with every individual car which is transformed to a point in the network. V2V communication relies on a reliable and timely vehicle self-organizing network, which is now known as VANET (Vehicle Ad-hoc Networks). VANET serves to provide information about other vehicles.

6.2 Process

First, the basic purpose to measure the distance is to judge whether the distance would be enough for avoiding an accident. The strategy is to analyze whether any two cars have the probability of collision. The value of location, speed and direction of the vehicle is needed to be completely analyzed. After determining their routes will be overlapped at some point, namely, they would collide at that point, it would, basing on the velocity collected and prediction of the behaviors of vehicles around, effectively avoid the collision by applying some confinements.

Second, according to physics laws, the interaction between two cars can be divided into different phases. For example, there are several phases partitioned on the basis of a specific distance with

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increasing possibilities of having accidents. In each phase, the computational processor would calculate an interval of safe velocity. Additionally, there would be more phases divided, more accurate interval calculated and such an interval could work as a guidance for confinements.

Third, with the information of location, the problem of blind zone could be solved. Obviously, the sensors would detect the distance of the vehicles around, despite the blind zone caused by the vehicle itself. However, some blind zone is caused by obstacles, namely the wall or the vehicle itself. This could also be solved by the network through analyzing the relative motion trail. Conclusively, the computation is a continuous procession to set safe intervals according to the prediction of other vehicles.

6.3 Feedback

Based on the computation introduced in 2.2, with the technology of AR (Augmented reality), whether driver is at a fate status could be visualized, as figure shown at the right side.

The confinements this system would make are all about the linear and angular velocities of the wheels of vehicle. According to the analysis finished by the processor, in different phases as cataloged in 2.2, different maximum velocity and minimum velocity values are set to limit the behavior of the vehicle. Combined with the fact that people may be unconscious about the various limitation threshold, this kind of confinement would be realized by the resistance of transmission. For example, if the vehicle is cataloged into phase4, it will be really dangerous to change the velocity suddenly. Therefore, sudden changes must be forbidden in this system. Driving at a safe velocity approved by the central processor would not evoke the confinements. However, if the velocity is much over the safe one, the confinement will be done since the increased resistance of the transmission limits the maximum velocity a car could reach. Such a strategy will ensure the safety of the driver, as well as exert little influence on the habits of the driver, which had often been regarded as the inconvenience. Generally, in each direction of the vehicle, there are different values of limitation, which optimizes the convenience and efficiency of drivers at the premise of safety.

7. Conclusion

Besides the collision avoidance, there are many other fields that can utilize the Assisted-Driving system. Assisted driving, for example, is one of the many fields which helps drivers to improve their driving performance on roads. Insurance company, on the other hand, can use the data collected by the system to monitor the driving habits of insured clients such that the insurance company can give out proper discount based on these performances. Police department can also use these analyzed data to undertake certain tasks in order to maintain the traffic security. It is worth noting that these mentioned applications are large scale applications. However, the ADS system is also capable of carrying small scale applications such as vehicle theft protection, parking assistant, and low degree automation.

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