香港城市大學
City University of Hong Kong

CS2066 IT Professionals and Society
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Project 2: Topic 2
V2X Communication Proposal

Submitted by Group 29, Group Name: Team IT Pros

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1. Introduction

Vehicles have evolved tremendously and in different directions since their invention. Especially after the third industrial revolution, and now during the fourth one, with the rapid growth of the high-tech industry and the development of information and communication technologies, vehicles are developing at an incredible speed. Today, people expect more than quality and reliability from a vehicle. Vehicles are expected to be equipped with advanced safety systems and wireless capabilities. Nowadays, we can already see vehicles on the road running in semi-autonomous mode using safety features such as assisted parking and braking systems. These vehicles are equipped with a variety of technologies such as radar, lidar, cameras, and other sensors that allow them to operate independently. However, today most autonomous driving systems are only partially automated. SAE J3016 "Levels of Driving Automation" [1] standard defines six levels of driving automation, from SAE Level Zero (no automation) to SAE Level 5 (complete vehicle autonomy). According to Fig. 5.1, only level 3 driving automation can drive a car without a driver, but only in limited conditions. Nonetheless, most autonomous driving technologies are currently considered level 2, with the most advanced of them being between levels 2 and 3. These automated vehicles have a considerable impact on reducing road accidents, but the lack of V2X connectivity still creates some problems. It is still being expected that this technology will be mainstream in the near future, even though it is not perfect.

The problem that people face today is a general lack of connectivity of vehicles. This results in poor mobility and safety of road transportation systems. Furthermore, with high technological advances in recent decades, the population of vehicles is increasing at rapid speeds. This causes traffic congestion on roads, leading to a series of problems in terms of high economic costs and environmental problems. As road transport accounts for one-fifth of total CO_2 emissions worldwide [2], the problem of mobility needs to be solved. Also, internal combustion engine vehicles consume energy even in static mode in a traffic jam. In fact, they consume 20% more fuel, which means that valuable resources are wasted. In addition, the problem of safety needs to be addressed. Although the number of car accident survivors has increased significantly due to modern safety technologies, accidents should be prevented from happening in the first place. Car crashes can be caused by many factors, such as weather, poor road conditions, and vehicle failure. However, according to research, human error is the number one cause of ongoing car accidents [3]. Connected vehicle technology has the potential to significantly minimize car accidents caused by human error by providing various technologies like collision avoidance and blind-spot support systems.

2. Design and Innovation

The IT solution we have decided to use is to implement a Vehicular Ad Hoc Network (VANET) with Dedicated Short-Range Communications (DSRC) wireless communication technology that enables vehicles to communicate with each other and other road users directly, without involving cellular or other infrastructure.

2.1 Implementing VANET using DSRC

DSRC is a wireless protocol for vehicle-to-vehicle communication which is used to provide drivers with information about other vehicles that are beyond the normal range of vision. It can transmit signals to all vehicles, such as position, speed, acceleration. It also sends out vehicle control information such as brake status, steering wheel angle, path history and path prediction. This allows for development of driving support systems such as intersection movement assist. By the information provided, if the crash is predicted at the intersection such as running the red light, the vehicle warns the driver either by seat vibration, display or voice. The system will provide warning only and the driver retains control of the vehicle, and it will not automatically slow down to ensure safety [4].

DSRC equipment consists of vehicle Based Components which are onboard units (OBUs). DSRC radio, which is responsible for receiving and sending data. It is normally mounted in or on a vehicle and can also be a portable unit. GPS Receiver which provides the vehicle position, time to DSRC radio and a memory storage unit to store all the driving data. Roadside units (RSUs) are also required, they are transceivers mounted along a road for receiving and sending data. These components work together to create a wide Network [5].

2.2 Comparison with existing technologies

Our implementation of VANET is a significant improvement over the existing solutions. The VANET can share the position and speed of the car with all the cars nearby. This provides more information than using hand signals and lights present on the rear of the vehicle. Use of the VANET can also help get rid of a driver's blind spots as it shares the relative positions of the cars. This can make the roads safer. Infrastructure can also send signals to vehicles, making it easier for traffic police to manage cars than hand signals.

As we are using DSRC for our wireless communication, direct line of sight is no longer required, unlike WAVE used in the solution proposed by Bergenhem, et al [6]. This allows vehicles utilizing our solution to communicate around corners and is not blocked by other vehicles or infrastructure on the road. Furthermore, our solution allows for a more dynamic vehicle-to-vehicle network, and the vehicles involved do not have to be pre-verified. They are allowing us to create a more general-purpose vehicle network than the platooning system designed using WAVE. Additionally, the WAVE solution was developed to enable a human-driven vehicle to communicate with autonomous vehicles, limiting its use. We can communicate to and from both autonomous and human-driven vehicles to provide complete information on the road and promote safety.

Our solution also improves the "optical communication with the LED" solution proposed by Takai et al [6]. In their solution, a forward-facing camera on a trailing vehicle captures the rear lights of a leading car and uses image processing to decode a signal. This whole process can involve a lot of latency. Our DSRC VANET can send signals at under 50 ms allowing for quick communicating and making the information available to the drivers more up to date. Furthermore, the DSRC uses an uncommon 5.9 GHz frequency, allowing fewer disturbances than the LED solution. The LED solution is also more susceptible to bad foggy weather. Unlike the LED solution, our solution also supports 2-way communication and can send and receive signals 360 degrees around the vehicle. It also has a significantly higher rate of data transfer at 27 Mbps compared to the other solution. These advantages over currently available technologies show that VANET using DSRC is one of the better solutions for vehicle-to-vehicle communication.

The implementation of technologies mentioned in our solution are designed to allow for V2X communication utilising ad-hoc networks (VANET) instead of networks consisting of multiple bands such as the Universal Mobile Telecommunication System (UMTS). Considering an Inter-Vehicle Communication (IVC) protocol adopted by the European Commission and car industry of an additional channel included in the UMTS unit [7], comparisons can be made between the effectiveness and efficiency of the proposed implementation in this report, and this existing application.

As previously discussed, Vehicular Ad Hoc Networks (VANET) offer a number of important advantages over Universal Mobile Telecommunications Systems (UMTS); the most useful benefit of implementing VANET instead of UMTS for our proposal would be the ability for vehicles to communicate directly with each other without requiring a middle ground or an interface (such as the air interface in the aforementioned existing solution).

Taking the direct connectivity feature of VANETs into consideration, it could be predicted that there is faster data transfer between vehicles that utilize this implementation. On the contrary, routing information transmission through these ad-hoc networks takes place at a slower rate than other types of networks and "end-to-end delays" tend to occur [8]. This is a highly likely potential weakness of our solution proposal; belated transmission of vehicle data including the speed, acceleration and path prediction could result in grave situations such as traffic accidents due to collisions that were unable to be prevented by cause of a lack of timely communication between vehicles.

Furthermore, VANETs may not be particularly secure – these networks could be rather easily intercepted, resulting in a breach of user privacy. VANETs would need to be secured before being implemented on a large scale using a cryptographic implementation [9]. This characteristic of these ad hoc networks derives from the networks being a subgroup of Mobile Ad Hoc Networks (MANET); MANETs are unsecured networks [9]. The lack of security of these vehicular networks could lead to dangers such as getting tracked down by an attacker intercepting communication between the vehicles.

Dedicated Short-Range Communications (DSRC) is a relatively common and preferred service type in the field of smart-vehicles and vehicular communication as it is more effective at data transmission between moving machines than other services such as LTE [10]. It is important to note, however, that DSRC underperform in transferring large packets of data between vehicles compared to LTE [10]. This could pose a potential issue in the future usage of our implementation; transmission of small blocks of information on position and acceleration of a vehicle is likely to be only currently sufficient. As technology is constantly getting adapted to be able to transmit ever-increasing amounts of data, it is inevitable that our suggested implementation will need to utilize a non-DSRC service to be beneficial to future users.

3. Demo

In this part, we would like to demonstrate the implementation of VANET via the DSRC property mentioned in the above sections, namely: position, speed, direction to compromise the crash before it happened in our simulator environment.

3.1 Definition of simulation

Before making the simulation, these variables were fixed in our simulator to ease the process and help to understand the experiment.

1. All vehicles in the simulator are auto-drive.
2. All cars use the same Algorithm to run (which will be explained in the next part)
3. Only data from the DSRC (position, speed and direction) shall be broadcasting in the fixed range as the radio signal behaves in the physical world.
4. No additional variables from the calculation will be added to broadcast through DSRC to prevent a heavy load of the computational power of each car and secure the safety of all vehicles equally.
5. In initialization, the car moves with constant speed until the Algorithm detects the prospective crash.

3.2 Algorithm

To simulate the car drive, it needs to have Algorithm behind those cars. We define the status of the vehicle in the following list.

- Running : The car is moving with constant speed (auto-drive)
- Emergency : The emergency trigger was on, and the vehicle was slowing the speed until it stopped. The direction depends on the Algorithm to avoid crashing.
- Stop : The car has stopped entirely without crashing.
- Crashed : The car has crashed.
- Out : The car is already out of the screen.

The status of each car will be displayed throughout its radar's colour in the back of the car colour (the small blue circle).

Every car will have Running status as default until it moves close to any other car in the radar range. After the vehicle catches any other car signal, it will switch to Emergency status and break the movement with constant negative acceleration. Along with slowing down, the car will continuously receive the neighbour DSRC signals until it stops entirely. The data from DSRC (position, speed and direction) will be calculated for making rotation decisions as stated in the following chart (Supplements 5.2) for making a safety stop.

However, this Algorithm was not guaranteed that it was the best way of using DSRC data. Still, this Algorithm is only for demonstration of how DSRC data can be used in self-driving mobiles to prevent predictable crashes. Mass usage of this technology still needs to be tested before using it as the central Algorithm for all future cars.

3.3 Scenario examples

3.3.1 Triangle Crash

For the first example, we will look at three cars; each is directed at the same point with the same velocity. After simulating for a while, within the signal range, all vehicles exchange the DSRC (position, speed and direction) property and determine the crash. Finally, all cars decided to slow down along with rotating right like human instinct reflections when driving on the right-hand side road system. (Supplements 5.3)

3.3.2 Y Crash

The second scenario was set after the first scenario, where all three cars had stopped safely. The fourth car appeared from the top of the canvas with the speed and direction toward the south, with those first three cars as solid obstacles. The car decided to rotate left after detecting the vehicle in the bottom because it is safer when the start position was slightly on the left side of the centre, unlike 3.3.2 Triangle Crash, where left and right are not different. (Supplements 5.4)

There are some more scenarios to be explored; as word limitation on this document, we couldn't try it all. Nevertheless, please feel free to try our simulation with our demo scenarios or create your own at https://h11maitree.github.io/Car-CAS/.

3.4 Demo conclusion

From the previous demo on our simulation, the data transmitted through DSRC and connected as a VANET network can help cars prevent accidents while using our Algorithm. Additionally, having suggestions from DSRC data could be beneficial to those non-auto drive cars drivers as the Algorithm was to set some parts based on human reaction.

4. References

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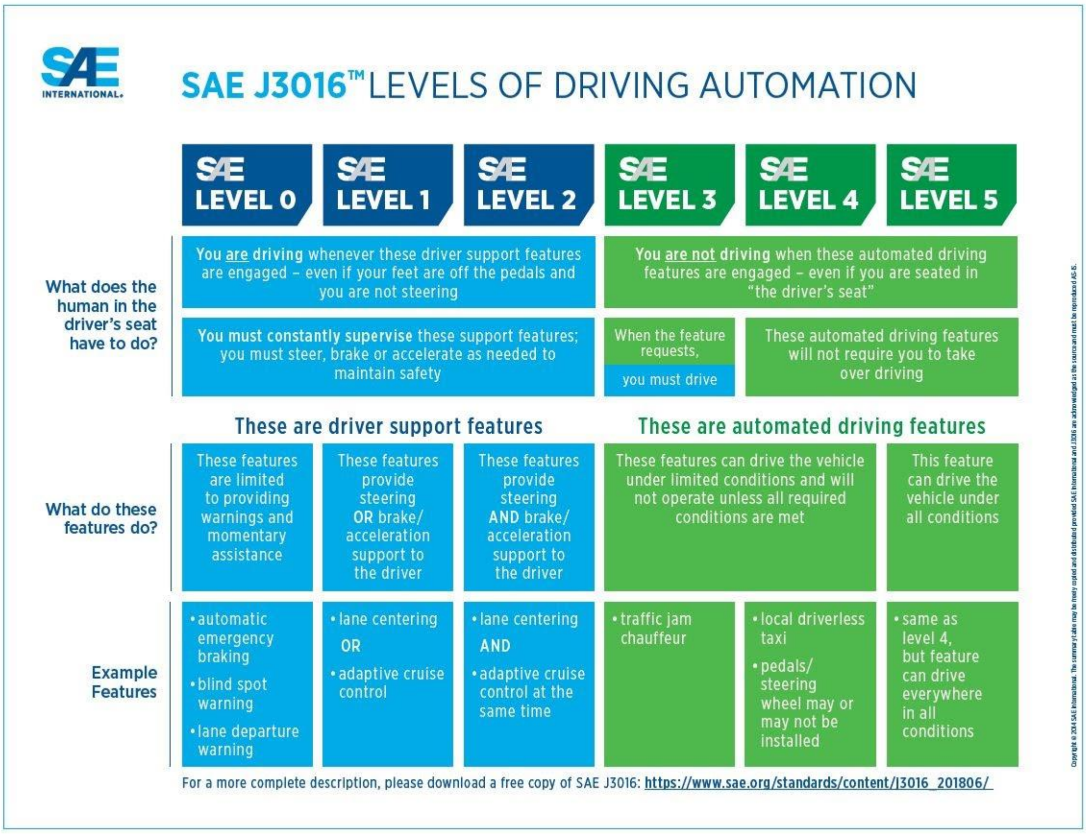
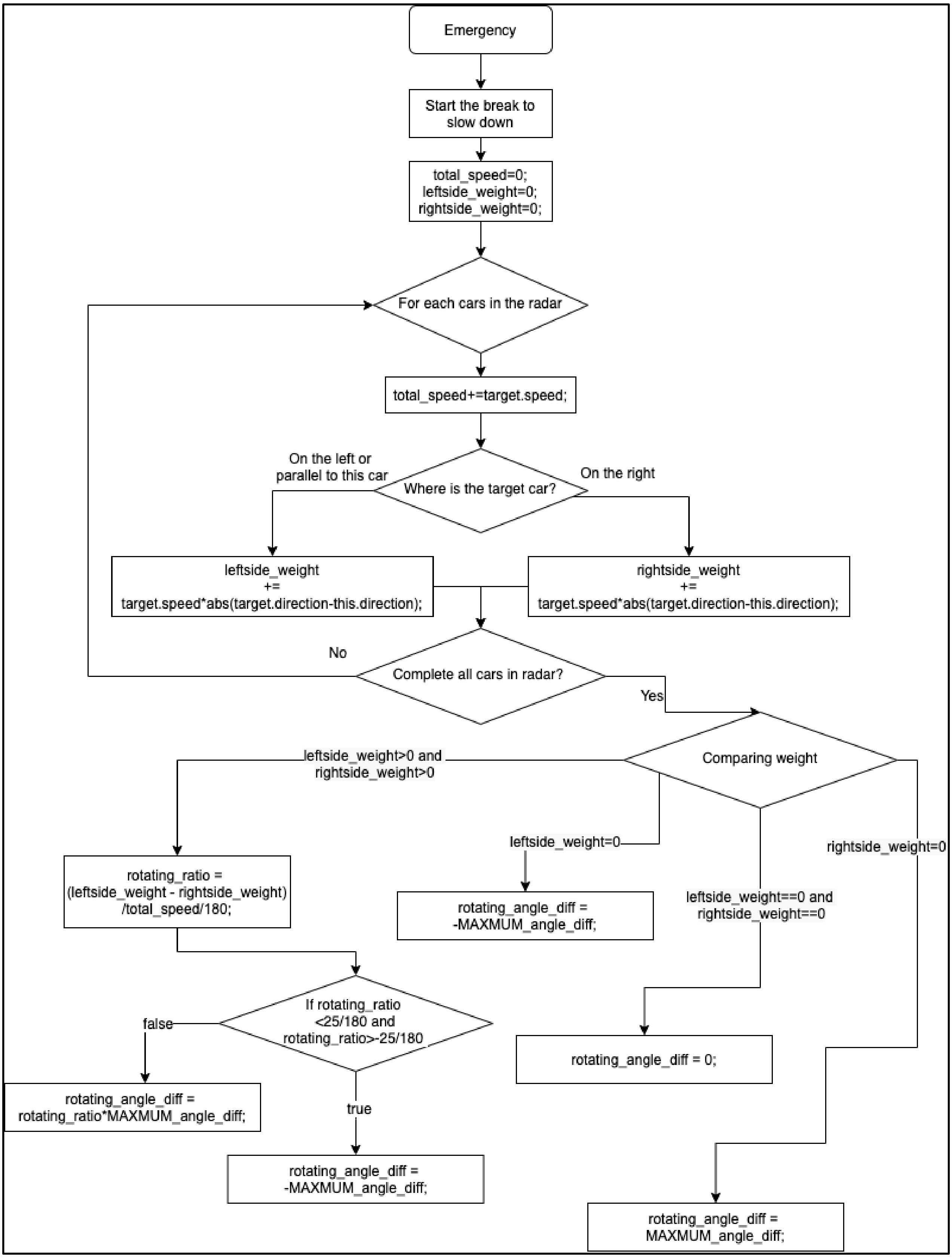
5. Supplements

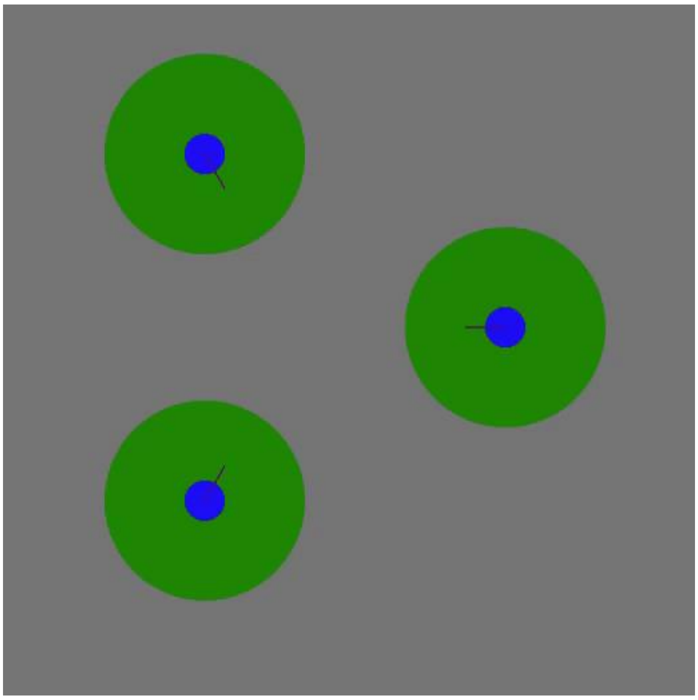
5.1 SAE J3016 “Levels of Driving Automation”



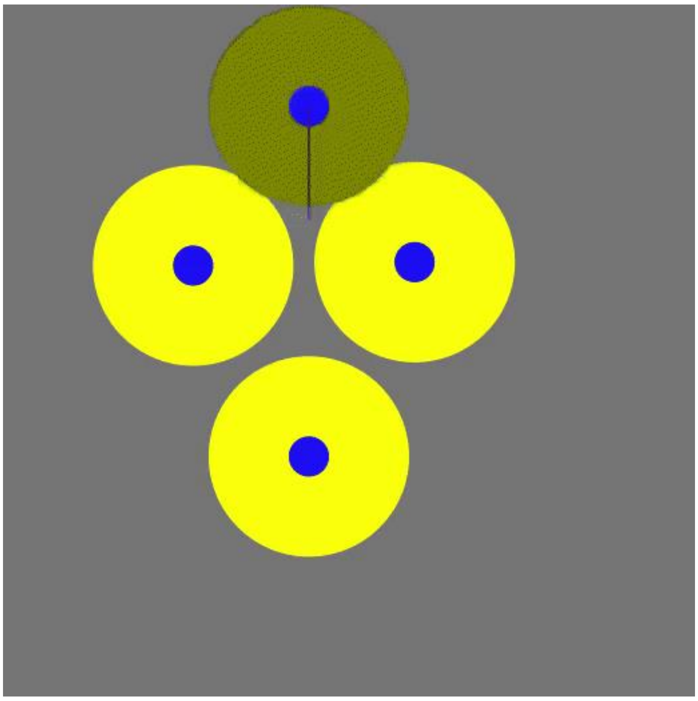
5.2 Algorithm Flow Chart of Cars in simulator under Emergency status



5.3 Triangle Crash
https://raw.githubusercontent.com/H11Maitree/Car-CAS/main/Picture1.gif



5.4 Y Crash
https://raw.githubusercontent.com/H11Maitree/Car-CAS/main/Picture2.gif



V2X Communication Proposal

Introduction

Problem description

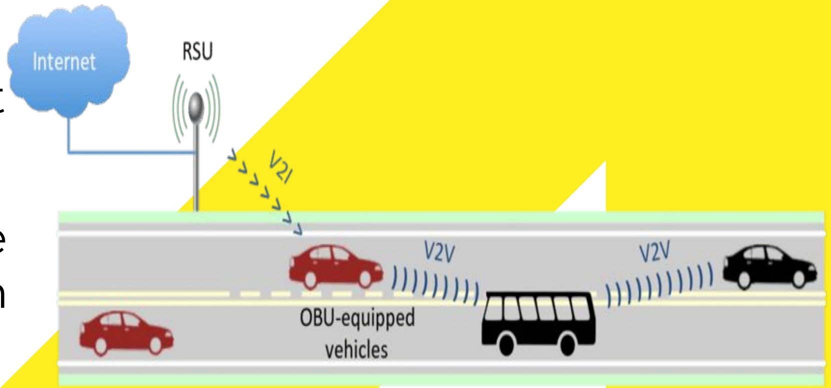
- → Lack of V2X connectivity
- → Low efficiency
- → Safety
- → Environmental impact

Design & Innovation

Implementing VANET using DSRC

What is DSRC

- Wireless protocol for V2X communication
- Provide drivers with information about other vehicles
  - position, speed, acceleration, brake status, steering wheel angle, path history , path prediction
- Development of driving support systems
  - warns the driver by seat vibration, display or voice



DSRC Components

Onboard units (OBUs)

- DSRC radio
- GPS Receiver
- Memory storage unit

Roadside units (RSUs)

- transceivers mounted along a road for receiving and sending data.

This creates a wide network for VANET

Comparison & Strengths and Weaknesses

Strengths

- VANET creates a more dynamic network allowing our solution to keep up with fast moving traffic
- DSRC signal spans 360 degrees and does not require line-of-sight
- Supports 2-way communication allowing for a more general purpose V2V communication system
- Low latency under 50 ms so all drivers have updated information
- Uses 5.9 GHz frequency so less prone to disturbances
- Has high rate of data transfer to allow the communication of more information

Potential Weaknesses

VANET:

1. speed of data/information transmission

2. security concerns (MANET)

DSRC:

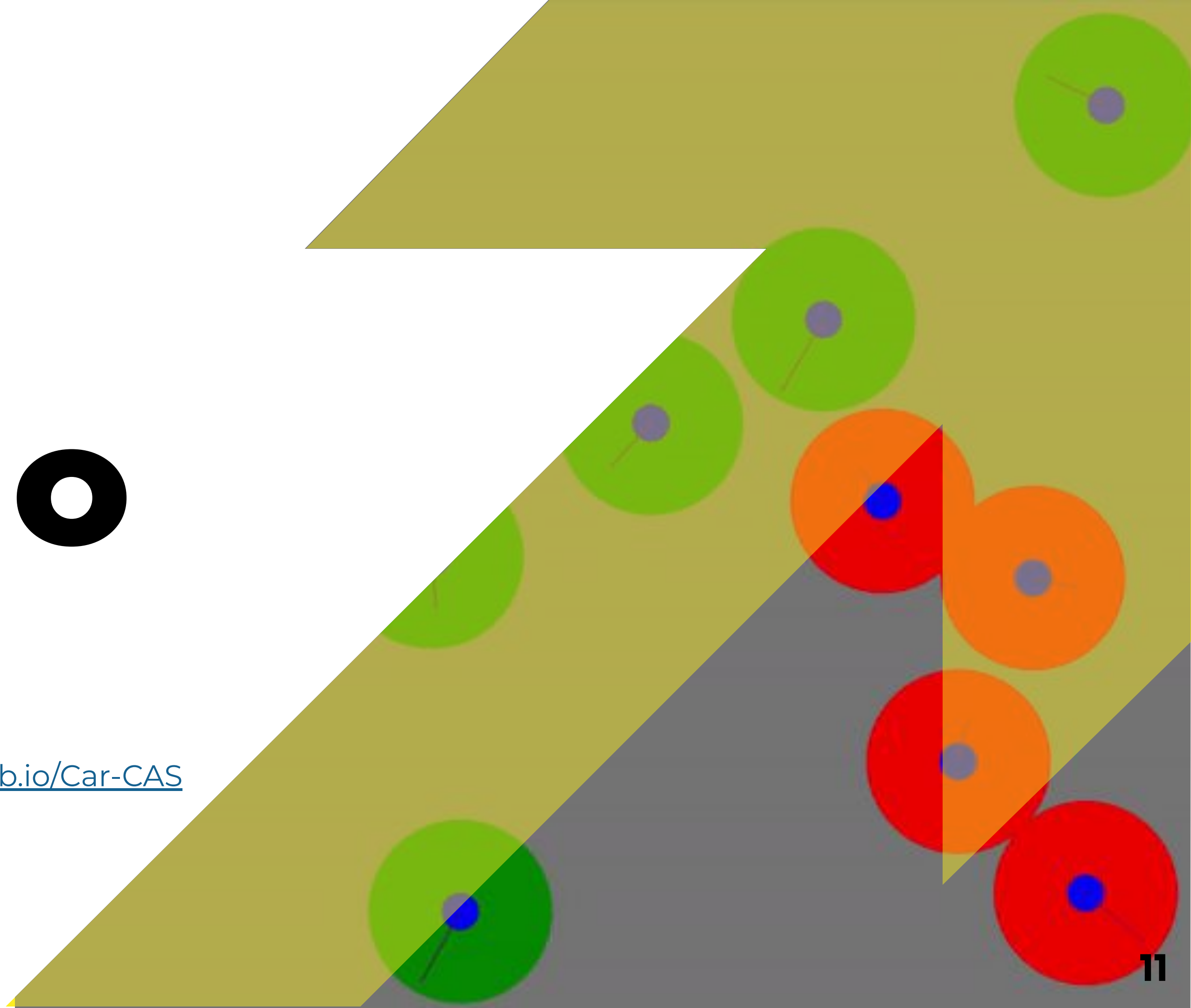
1. lack of support for transferring large bundles of data/information

Demo

Simulation

Applying V2X

Available at: h11maitree.github.io/Car-CAS



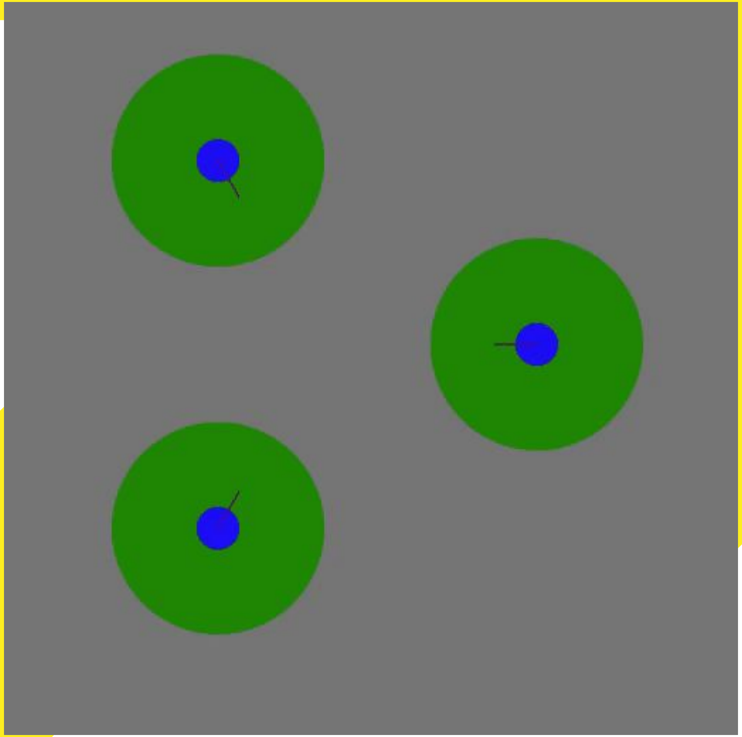
Triangle Crash

With DSRC data

→ speed
→ direction
→ coordinate

Cars can prevent perspective crash with algorithm*.

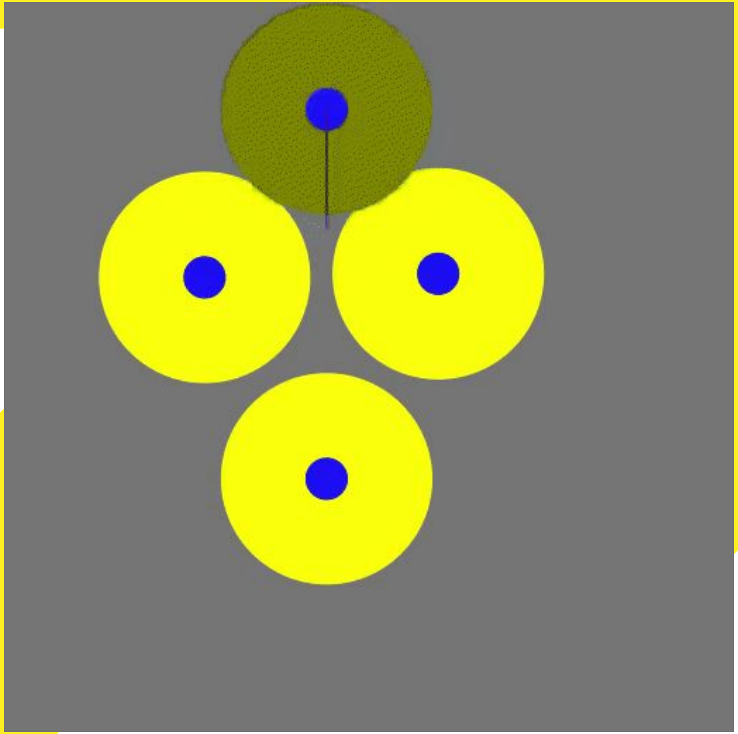
*For algorithm detail, using in simulator, see the full report.



Y Crash

The algorithm can decided to rotate left after detecting the vehicle in the bottom though VANET

As it is safer when the start position was slightly on the left side of the centre



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Thank you!

Any questions?