Autonomous Cruise Control for General Collision Avoidance of Road Vehicles

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Abstract. Autonomous Cruise Control (ACC) systems are widely used in automotive industry to maintain safe longitudinal distance between vehicles. The concept of maintaining safe distance is well applicable on straight roads, especially highways. We discuss the generalization of the concept on the general road network (e.g., junctions without traffic lights). We propose a generalization of the Safe Distance method – implementation of the ACC in the Agent-Drive simulation platform. The generalization is based on the idea of application of the ACC control on a virtual traffic situation. A real world traffic situation is transformed to the virtual situation, that is then maintainable by the prior Safe Distance method. The proof-of-concept experiments are presented. Our work promises interesting future work and proposes several directions of our research intentions.

Keywords
autonomous vehicles, coordination, multi-agent systems, simulation, ADAS

1. Introduction

Car transportation is a dangerous mode of transport. In 2011, more than 30,000 people died on the roads of the European Union [1]. There is a lot of concern how to make this mode of transportation safer. There is an ongoing development of passive and also active safety components in cars. Advanced driver assistance systems (ADAS) are examples of an active safety system. Assistance systems varies in the level of autonomy. Some systems offer a detection and warning of a dangerous situation, e.g., when driver needs to slow down to avoid a collision with a vehicle ahead. A more advanced system can even take control of the car in case of emergency situation. Fully autonomous – driverless cars are already tested on public roads. Automation can bring more safety and even more efficiency. Automated cars achieve significant efficiency boost in sense of usage of road infrastructure.

The integration of assistance systems or autonomous vehicles is a gradual process. The traffic is heterogeneous even in the sense of autonomy. We are interested in coordination techniques that are applicable in such heterogeneous setting. Particularly, we build our method on principle of an existing driver assistance system. We propose a concept of generalized autonomous cruise control.

2. Problem Specification

The problem of a multi-agent coordination is described in this section. First, we define the environment – the road network. The road network is a graph structure. Junctions are nodes and roads connecting junctions are edges. There are optionally more lanes in one edge and every lane is directed. All the components have coordinates and dimensions in 2D. Vehicles move freely in the 2D space, but respect the underlying road network. Every vehicle is driven by a related agent. Every agent has a specific destination and knows a sequence of edges of road network to get there. Agent is able to generate and follow a path towards its destination. The problem to solve is a collision avoidance. We need the agent to follow its sequence of edges while avoiding collisions with other vehicles. The agent is able to adjust vehicle’s speed and also adjust trajectory, e.g., change lanes. The control is online, i.e., the agent is repeatedly sensing vehicle’s state and considering the next control inputs. The sensing is considered to be perfect (i.e., agent knows positions and velocity vectors of others) in a limited radius.

We assume junctions without any traffic rules nor traffic lights nor signs. The agents form a multi-agent system without any particular communication between agents. There is also no negotiations with other agents, agents only react on other agents behaviour. This system is decentralized.

3. Proposed method

Our approach is based on principle of Autonomous Cruise Control system. We describe the principle in the Sec-
tion 3.1. Considering the functionality of the ACC system, we propose mechanism using the ACC system as its core component for collision avoidance.

### 3.1. Autonomous Cruise Control Functionality

Adaptive Cruise Control (ACC) is an automotive feature that allows vehicle to adapt the vehicle’s speed. A radar system attached to the front of the vehicle is used to detect whether slower moving vehicles are in the ACC vehicle’s path. If a slower moving vehicle is detected, the ACC system will slow the vehicle down. If the system detects that the forward vehicle is no longer in the ACC vehicle’s path, the ACC system will accelerate the vehicle back to its set cruise control speed. This definition is used in [2].

### 3.2. Generalized Autonomous Cruise Control

As Autonomous Cruise Control system can maintain the safe distances between vehicles behind, interesting thought is to trick this system, that vehicles that are heading to the junction from another roads are in front of him in some specific distance to the junction. This would force this system to make safe distance between my car and the vehicle which is also heading to the junction. This would allow them to pass junction safely. The main problem in here is how to virtually put another vehicle before me? For this purpose, location and velocity of another vehicle and precise road map is required. From the location of another vehicle its distance to the junction can be calculated using the location and the road map. As we know the distance to the junction we can compare it to ours distance. If it is closer to the junction we can try to set it as vehicle before me. We can try to set multiple vehicles and take into account only the closest one. Autonomous Cruise Control system guarantees safe distance between me and the vehicle before me, so if this is activated far enough to the junction, all vehicles will create safe-distance between them and with safety reserve big enough it allow them to pass the junction safely.

![Fig. 1. Simple situation, two cars are heading to the junction. Car 1 is a bit closer to the junction than car 2.](image1)

![Fig. 2. Translated situation in 1 to the situation where these two cars are on the same road. The order, the distance to the junction and the velocity of each vehicle are preserved.](image2)

### 4. Proof-of-concept experiments

We made several experiments to proof this method's functionality. We picked two most representative ones. Both scenarios are the full junction with 90 degrees angles between the roads. The shape of the junction is irrelevant for this method, only thing which matters is number of roads heading to the junction. The difference between these two scenarios is only in how much vehicles are approaching the junction. As it can be seen from the figure 4 and more clearly from figure 6, all vehicles sorted themselves on the road to the junction and passed the junction safely. The reaction between the vehicles can be well seen in the 6 as all vehicles were forced to adjust their speed to the second vehicle which was turning right. It can be clearly seen from which distance was this method activated. This method allows only one vehicle in the junction.

As it can be seen on these figures, this method gives nice results and we are presenting these experiments as a proof of concept. For the testing purposes, the Safe-distance method proposed in [3] is used as Autonomous Cruise Con-
trol. We are calling this method the Narrowing mode as it was originally named in the Safe-Distance method.

Safe-Distance method as the name suggests is designed to keep safe distances between vehicles. This method was designed for Highways and has one key ability which ACC does not have. It is the ability to switch lines in order to solve the situation. Not only to decrease and increase speed.

4.1. Implementation: Safe-distance method

Safe-Distance method requires two inputs to work. Position of an agent’s controlled vehicle and positions and speeds of car’s nearby. For the situation when the car is only on the road that contains only one lane in one direction it is only necessary to know the position of the nearest car ahead. Position of the car behind can be omitted because this car can adjust it’s speed to the our vehicle.

This method is the reactive method because all agents react on what they see and they don’t communicate with each other. For example we can take a situation in which there are three cars on the straight road. They keep safe-distances between each other so they can safely decrease their speed if necessary. The first car can decrease the speed without caring about cars behind. This is because the second car will have enough time to react. Same principle can be applied to the third car. Situation changes when there are multiple lanes. It is necessary to know the position of the nearest car behind and nearest car ahead in the next lane for the safe lane changing.

Output of this method is a plan consisted of manoeuvres. Simple plan for example can consist of two manoeuvres:

1. Decrease an agent’s car speed.
2. Switch to the next lane to avoid a collision with an object on the road.

Let’s summarize which cars nearby are necessary to be considered for the Safe-Distance method. We need to know the position of the car ahead, the car in left and right lane ahead and cars left and right behind if these lanes exist. These cars are stored in the car’s Storage. The Storage is basically an object in which all the nearest cars in all the listed directions are saved. Safe-Distance method uses this Storage to make decisions. Full description of the original Safe-Distance method can be found in Chapter 4 of [3].

4.2. Simulator Environment

For the testing purposes the Simulator-Lite was used. The simulator gets plans of all vehicles from the method. Simulate them. Return its new location to each vehicle. This simulator uses basic physics model. It takes into the account the actual velocity, the acceleration and the capabilities of the selected vehicle. This simulator allows to control the method outputs and check if the plans are real.

![Fig. 3. Simple testing junction. Every car is 200 metres from the centre of the junction](image)

![Fig. 4. This figure shows every vehicles distances to the junction in the selected time. First car has a plan to cross the junction straight, Second vehicle has a plan to turn right and the last two vehicles have also the straight plan. The Narrowing mode was activated 150 metres from the junction. This happens around time 45. From this distance on, they are aware of each other and they start to maintain safe distances. Safety distance reserve is 10 metres. All vehicles started with zero velocity. As you can see in this figure, last two vehicles needed to adjust their speeds to maintain safe distances between them. Number of collisions is 0.](image)
5. Conclusion

Advantages of this method are:

1. It is a reactive method, so the calculations are fast.
2. Using existing system – ACC.
3. Easy implementation.
4. Simple solution.

Disadvantages of this method are:

1. It allows only one vehicle in the junction.
2. Ignores traffic rules. It can be improved as it is proposed in 6.

This method is based on the Safe-Distance method proposed in [3], it expands it allowing the original Safe-distance method to be able to navigate throw junctions. Original Safe-distance method was only designed for Highways. The main problem is to get the vehicles location data, this method requires to work property location sensor in every vehicle beeping its location. This method can also work without it, but with limited abilities.

6. Future Work

This method can respect traffic rules, it can be done by prioritizing vehicles on the main road. All vehicles on the main road can be virtually put in front of the vehicles on the side road.

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References


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David KUBEŠA was born in Prague, Czech Republic. He is currently working on his bachelor thesis at CTU.