A Collaborative Rear-End Collision Warning Algorithm in Vehicular Ad Hoc Networks

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Abstract. How to solve rear-end collision warning problem has become an increasingly tough task nowadays. Numerous studies have been investigated on this field in past decades, either time-consuming or with strict assumptions. In this paper, we have proposed a collaborative rear-end collision warning algorithm (CORECWA), to assess traffic risk in accordance with real-time traffic data detected, transmitted and processed, by vehicles and infrastructures in vehicular ad hoc networks (VANETs) collaboratively. CORECWA considers some influential factors, including space headway between the two preceding and following vehicles, velocity of these two vehicles, drivers' behavior characteristics, to evaluate the current traffic risk of the following vehicle. Experiments results demonstrate that CORECWA can gain better performance, compared with a well-acknowledged algorithm *HONDA* algorithm.

Keywords: Rear-end collision warning · Vehicular ad hoc networks · Traffic risk assessment

1 Introduction

Traffic collision has become a huge problem worldwide that brings inestimable economic and social losses. Rear-end traffic collision make up nearly 30 % traffic accidents in China according to a survey in 2012 [1], which refer to a vehicle can not control its velocity effectively to avoid bumping against the preceding vehicle. Hence, when to warn the drivers in advance the emergency and how to warn them have attracted numerous researchers' attention. This problem involves many issues, including real-time traffic data collection, data collaborative transmission and processing, decision making and so forth.

In the past decades, a large number of studies have been carried out in rear-end traffic collision problem. Previous work can be classified into two groups, including artificial intelligent methods and mathematical methods. Lots of researchers have proposed AI techniques to study drivers' behavior (i.e. perception reaction time) which can help determine when to warn the drivers in emergent moment in advance. A driving-assistance system has been developed and drivers' behavior can be identified to help generate traffic collision warning

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message [2]. Fuzzy theory and BPNN have been utilized to develop approaches to generate warning notice in advance and determine minimum traffic safety distance between the preceding vehicle and following vehicle [3,4]. On the other hand, numerous scholars have developed mathematical approaches to determine the minimum traffic safety distance or minimum traffic safety time with the consideration of perception reaction time, which can be treated as the threshold value in the algorithm design [3,5–10].

In this paper, we propose a COllaborative REar-end Collision Warning Algorithm (CORECWA), to develop warning message and remind the drivers when neccessary, with the collaborative work of vehicles and infrastructures in vehicular ad hoc networks. Real-time traffic are detected, such as velocity, position, acceleration and so forth. These traffic data are transmitted and processed collaboratively, to help the following vehicle make decision whether to generate warning message and remind the driver. Experiments are conducted to evaluate CORECWA's performance with a public available dataset, and the results show that our CORECWA would gain better performance compared with *HONDA* algorithm.

The remainder of this paper is organized as follows. In Sect. 2, we formulate the rear-end collision warning problem, and propose CORECWA algorithm in Sect. 3. Experiments and analysis are presented in Sect. 4, and Sect. 5 concludes this paper.

2 Problem Formulation

To model the rear-end collision warning problem, a typical scenario (presented in Fig. 1) should be taken into consideration [11]. The road can be covered by the four roadside units (RSUs), and all the vehicles in this road can communicate with each other and RSUs.

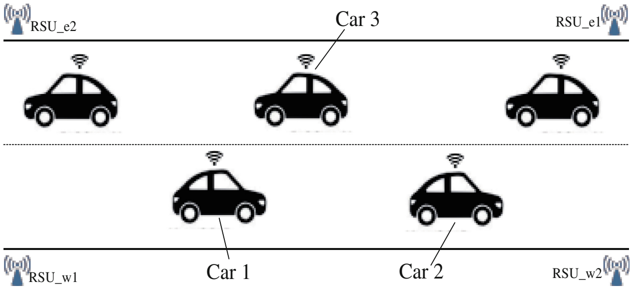

Fig. 1. A typical traffic scenario

Our problem is to find the preceding vehicle of a certain vehicle and evaluate traffic risk of this certain vehicle according to the traffic data collected collaboratively. Here, $TR(V)$ is defined as traffic risk of vehicle V. Our objective is to compute $TR(V)$ based on the real-time traffic data, and then determine a maximum value $Thresh(V)$ (shown in Eq. 1) as threshold of $TR(V)$ whether to warn drivers the emergency.It is obvious that distance computation is very critical. $Dst(V_1, V_2)$ is defined as the distance between V_1 and V_2. Moreover, $vlc(V)$ is defined as V' speed.

$$Max \quad Thresh(V) \tag{1}$$

3 Our Collaborative Rear-end Collision Warning Algorithm

In this section, we propose a COllaborative REar-end Collision Warning Algorithm (CORECWA), including two stages: the preceding vehicle confirmation, traffic risk computation and assessment. The preceding vehicle confirmation part focus on finding out the preceding vehicle for a pre-defined vehicle, with utilization of all traffic data collected by vehicles and RSUs collaboratively. Traffic risk computation and assessment part mainly work on computing the real-time traffic risk of the pre-defined vehicle, and compared with $Thresh(V)$ to make decision whether to remind the relevant drivers.

When considers the preceding vehicle confirmation, it not easily rely on the minimum distance between the pre-defined car and other cars. Taking *Car* 1 in Fig. 1 as an example, it is obvious that *Car* 2 is the preceding vehicle rather than *Car* 3 which has the nearest distance to *Car* 1. Therefore, when confirm the preceding vehicle, all the vehicles moving in the same lane should be identified first, and then confirm the vehicle with the nearest distance with the pre-defined vehicle as the preceding vehicle. The whole work has been presented in Fig. 2 [11].

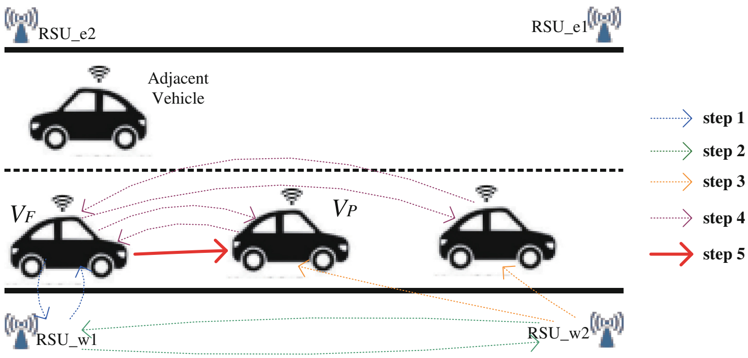

Fig. 2. The preceding vehicle confirmation (Color figure online)

At first, we should confirm all the vehicles in the same road with vehicle V_F. As blue lines shown in Fig. 2, when V_F enters into the road, it should communicate with the nearby roadside unit as RSU_w1 to inform its presence.

After receiving the inform message, RSU_w1 would communicate with RSU_w2 in green lines, so that the two responsible RSUs all know V_F. And then, the two RSUs collaborate to inform the vehicles in this same road the entry of V_F in orange lines. After informed V_F, all the other vehicles in front communicate with V_F in purple lines. The vehicle in the same road V_F with minimum distance should be treated as the preceding vehicle after comparison by V_F in red lines of Fig. 2.

Furthermore, traffic risk of V_F should be computed and assessed and defined as $TR(V_F)$. Let's assume a traffic scenario, vehicles V_P and V_F are moving with traffic speed $vlc(V_P)$ and $vlc(V_F)$ respectively. After a duration T, V_F has moved a distance defined as $s(V_F)$ with acceleration rate $a(V_F)$, and V_P has moved a distance defined as $s(V_P)$ with acceleration rate $a(V_P)$. Hence, $Thresh(V_F, V_P)$ should be greater than the different value between $s(V_F)$ and $s(V_P)$ as presented in Eq. 2. Perception reaction time, defined as $PRT(V)$, should be taken into consideration, which of different drivers may vary from 0.5 s to 2.5 s [12,13]. Therefore, the traffic risk of V_F, as $TR(V_F)$, can be calculated in Eq. 3.

$$\begin{aligned} Thresh(V_F, V_P) &\geq s(V_F) - s(V_P) \\ &= (vlc(V_F) - vlc(V_P)) \times (T + PRT(V_F)) \\ &\quad + \frac{1}{2}(a(V_F) - a(V_P)) \times (T + PRT(V_F))^2 \end{aligned} \tag{2}$$

$$TR(V_F) = \frac{Dst(V_F, V_P)}{Thresh(V_F, V_P)} \tag{3}$$

4 Performance Evaluation

We conduct simulations using a public database NGSIM to evaluate the performance of CORECWA, and compared with a well-acknowledged algorithm named as *HONDA* [6]. The traffic data of NGSIM used, including speed, location, acceleration, and so forth, are from Peachtree Street in Atlanta, Georgia, during 4:00 p.m. to 4:10 p.m. of November 8, 2006.

The dynamic changing of acceleration rate of the two vehicles are presented in Figs. 3 and 4. From the observation, we are able to find out that the acceleration rate of the following vehicle have influence from the preceding vehicle. The performance of HONDA algorithm is shown in Fig. 3. From the figure, we can find that in some part, *HONDA* algorithm is able to make correct decision in the some critical time. However, *HONDA* did not detect some important cases so that it can not send reminder message in these circumstances.

The performance of CORECWA is depicted in Fig. 4. From the figure, we can observe that CORECWA can detect more valuable and necessary moments than *HONDA*, especially when the preceding vehicle is in deceleration. When the preceding vehicle is in acceleration, CORECWA as well detects more cases than *HONDA*. That means our CORECWA can assess the traffic risk more correctly and precisely.

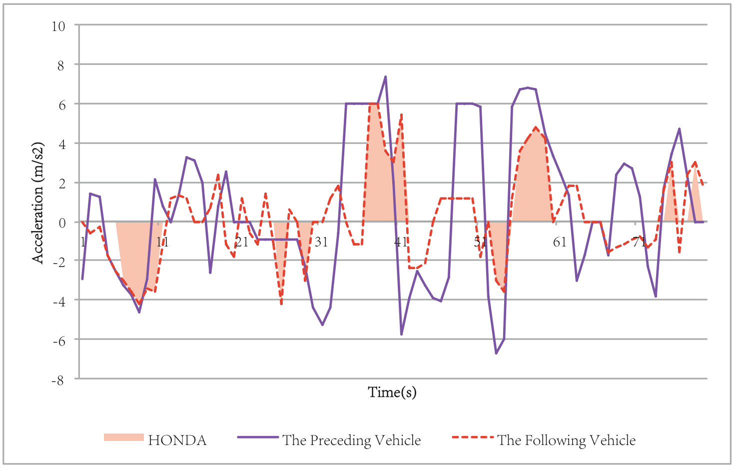

Fig. 3. Performance of *HONDA* algorithm

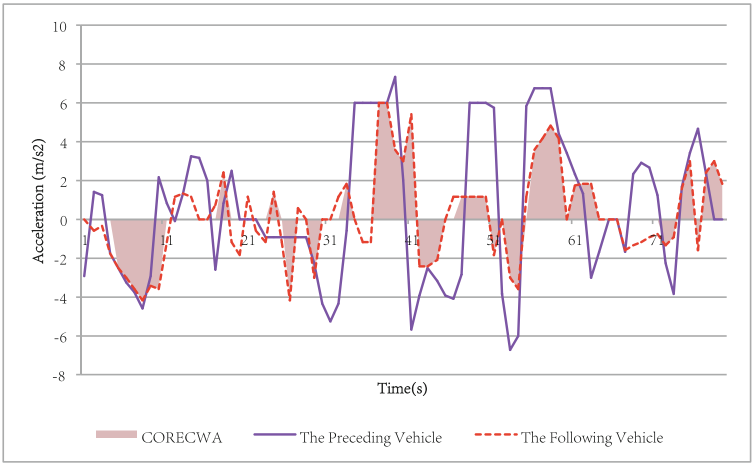

Fig. 4. Performance of CORECWA algorithm

5 Conclusion

Rear-end traffic collision warning problem has attracted more and more researchers' attention. We have developed a collaborative rear-end collision warning algorithm named as CORECWA, to inform drivers reminder message in the critical moment, when the vehicle may bump against the preceding vehicle. Vehicles and RSUs would communicate with each other collaboratively, through V2V, V2I and I2I communication, to help the pre-defined following vehicle to identify the preceding vehicle, and calculate the distance between them, with the utilization of vehicles' velocity, position and so on. Some experiments have been carried out. CORECWA has been evaluated its performance with comparison with *HONDA* algorithm, and the results depict that our algorithm outperform *HONDA*.

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