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An Effective Message Passing Approach to Predict Vehicle Collisions in a Single Lane Straight Road Segment

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ABSTRACT

Wireless communication among vehicles is emerging as an important method for developing road safety applications to reduce road accidents, which cause huge damage to human life as well as properties. This paper describes an efficient message passing mechanism for vehicular network in order to predict possible collisions in single lane straight road segment. This work is the preliminary results of an on going research on real-time collision predicting mechanism for automobiles, which will use WiFi based vehicular network testbed that will share data among the adjacent vehicles on the road, and processed information will be used to warn drivers about possible collisions. Researchers observed and collected data from straight road segments in Sri Lanka to identify influences of surrounding vehicles for potential collisions of a target vehicle, and the maximum number of participation of vehicles for an emergency event. Further researchers developed a model for positions of vehicles in the road segment and proposed an efficient approach for message passing among the surrounding vehicles for intelligent collision predicting mechanism.

Key words: Message Passing, Road Safety, Vehicular Communication

1. Introduction

There are number of road safety systems already being used by vehicle manufactures to ensure the safety of the passengers. But even today a significant numbers of lives are being lost due to road vehicle accidents. Most of the systems use Radar signals to detect abnormal movements or emergency events of the vehicles and other applications use GPS and vehicular communication techniques to share warning messages. Common human drivers suffer from perception limitations on roadway emergency events and responding to emergency warnings take much delay because humans have a Psychological Refractory Period (PRP) that limits the ability to respond to stimuli which are presented in close temporal proximity. Studies have shown that about 60% of roadway collisions [1]could be avoided if the driver was provided warning at least one-half second prior to a collision.

Researchers are focusing on developing applications which can communicate with other vehicles to propagate warning messages about a collision. Most of the applications are able to detect abnormal movements or emergency events of the vehicle itself and warn others through a dynamic vehicle to vehicle (V2V) wireless communication network when situations like stopping, decelerating, control loss, turnings at junctions and Lane changings. The driver of the receiving vehicle can then determine the relevancy to the emergency based on the relative motion between the warning message sender and himself [2].

In V2V communication, Short-range communications of 350 m can be accomplished using IEEE 802.11 protocols, specifically WAVE or the Dedicated Short Range Communication (DSRC) standard [3]. In vehicular ad-hoc networks, vehicles are converted into wireless mobile nodes and routers to create a network with a wide range approximately 100 to 300 meters of road side. However, the link quality of V2V networks cannot be expected to be in a good quality due to high mobility of vehicles, multi-path fading, shadowing and Doppler shift. As a result of that, there is a considerable probability of not receiving an emergency warning message when an emergency event occurs in the road. Therefore the objective of the proposed approach is to continually observe the surrounding vehicles' movements, predict their emergency events and inform the driver about surrounding.

Therefore, this project is based on a mechanism which keeps a track of surrounding vehicles' movements and predicts possibilities of collisions. Every vehicle will have a GPS receiver, external WiFi antenna and computer unit. A vehicle is to observe its location, speed and acceleration to create a message and pass it to the surrounding vehicles. A receiving vehicle will process the message via a comparison algorithm which tracks the location and actions of surrounding vehicles. To develop the algorithm of predicting collisions, it is necessary to have a model of message passing which defines the maximum participation of vehicles to be connected. This paper presents a model of vehicle positions on a single lane road and an approach of message passing to keep track of surrounding vehicles. To develop this model, the vehicular movements were observed in different roads and different places which have different traffic densities. Further, it was assumed that every road is in the same physical condition.

2. Statement of the problem

Even though V2V communication technologies have been developed and various road safety applications have been implemented, the number of deaths and injuries due to vehicle collisions is increasing day by day. This project is based on developing an algorithm of collision predicting and warning to avoid even collision possibilities. As the preliminary study of the above project, it was required to design a logical model of efficient message passing among vehicles by creating a minimum number of connection with surrounding vehicles. The purpose of this research is to observe real time movement of vehicles in single lane road segments and to identify the influence of surrounding vehicles movements for a driver's decision. Another purpose of developing this model is to uncover this area in which additional researches are required in order to develop collision avoidance applications.

3. Objectives of the study

The first objective of this study is to define a model of vehicle positions in a single lane straight road segment which describes the minimum participation of vehicles for predicting possible collisions. As the second objective, we try to identify minimum parameters to pass through a message via V2V communication to predict the movements of the identified vehicles. The final objective is to develop an approach for real-time message passing to respective vehicles to warn about possible collisions.

4. Literature Review

The mechanism of sending messages by colliding vehicle (CV) has been discussed in [4], which is based on one-hop notification delivery scheme for vehicles. When a collision happens, then the CV broadcasts the notification to the vehicles which are coming behind it. So, the drivers of receiving vehicles will decrease their speed. Vehicle to Vehicle (V2V) communication was used to send the message to the vehicles far from the CV position. But the number of hops will increase tremendously. Also because of the transmission of the number of messages, wireless traffic will increase which will lead to increase in collision of messages.

Clusters are formed for V2V communication in Cluster Based Simple Highway Mobility Model (SHWN) presented by B. Ramakrishnan in [5]. In this model, the vehicular network area will be divided into number of clusters where each cluster will have a cluster head. So the communication will be possible through cluster heads only. The cluster head can communicate among themselves. The time needed for any vehicle to send messages to a long distance will be more in case of cluster based model.

Emergency Electronic Brake Light (EEBL) [6] is an application which generates a message when the driver applies brakes to decelerate the vehicle and sends the message to surrounding vehicles via V2V communication. The receiving vehicle determines the relevance of the event and, if necessary, warns the driver. In this application the indication doing by the brake lights of a vehicle is passing as messages to the surrounding vehicles and collisions due to perception limitations of brake lights can be avoided. This application will be applied only for collisions with front end vehicles.

In Control-loss warning (CLW) [7]system it broadcast a warning message to the remote vehicles when a vehicle detects a control loss situation of itself. The remote vehicle warns the driver by determining the relevancy of the message. The drawback of this application is that the control loss vehicle broadcast the warning message after the emergency event. Then there will not be enough time to pass messages and avoid collisions with closer vehicles.

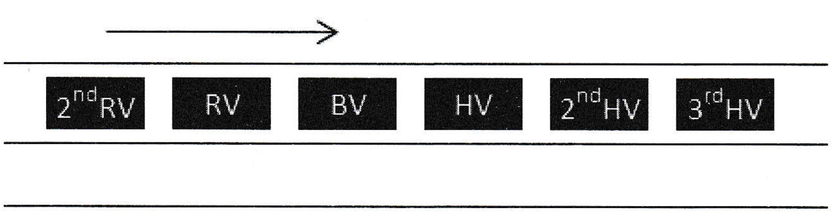
5. Methodology

The methodology used to develop this approach was contained with a preparation, observation and data analysis. The whole methodology depends on naked eye observations of road traffic in single lane road segments in different areas. There are three basic road classes in Sri Lanka namely Class 'A' (class 'AA', class 'AB', class 'AC'), Class 'B' and Class 'E' [8]. Since the paper mainly focuses on single lane roads, class 'E' was excluded from the population. Therefore the population consists of total12,173.19 km class 'A' and 'B' roads in Sri Lanka [8]. Our sample was confined to the selected road segments with consideration of traffic density and accessibility.

6. Preparation

In this study we considered six straight-road segments with different traffic densities for observation, and in each segment we had four observation points. We used a model of vehicle positions for this study which is shown in the Figure 1. Based on this model, we recorded acceleration/deceleration and relative speed of head vehicle (HV), 2nd HV, 3rd HV, rear vehicle (RV) and 2nd RV comparing to the base vehicle (BV). Further, relevant actions of the BV were also recorded to identify the influences surrounding vehicles.

Figure 1 : Logical model of vehicle positions for observation in straight lane segment. The arrow indicates the direction of vehicle motions. RV, BV, HV represents Rear Vehicle, Base Vehicle, and Head Vehicle respectively.



6.1. Observations

All together 24 observation points were visited to collect data and each point was observed for six hours. Five observers were used to record relative speed, relative acceleration and deceleration through naked eye view by comparing each vehicle to the base vehicle. Situations which have maximum four vehicles in the road segment were sufficient to collect the date for all five comparisons. When there are four vehicles in a single line, the first vehicle starting from back was considered as the BV and second, third, and fourth vehicles were taken as HV, 1st HV, 2nd HV and 3rd HV respectively. For the rear side third vehicle starting from back was considered as the BV and second and first vehicles as take as RV and 2nd RV. Situations which have two vehicles in the road segment were ignored because it increases the number of events of BV due to HV away from the purpose. When three vehicles were positioned in a line, data was collected for rear side and there were only four vehicles in the road they were considered as front side observations.

6.2. Analysis

All data recorded with five different observers for each observing location separated into two categories for front end and rear end. For each category three tables were created for recorded decelerations, accelerations and overtaking actions of BV. Tables of front end category has event number and relative acceleration change and relative speed change taken by naked eye observations of HV, 2nd HV and 3rd HV comparing to BV. For the rear end they have event number and relative acceleration change and relative speed change of RV and 2nd RV to the BV. Graphs were obtained by taking each action of surrounding vehicle to the vertical axis and the number of events to the horizontal axis to plot the influence of each surrounding vehicle to each action of BV separately. The following figures are for the graphs obtained for overtaking action of BV.

Figure 2 : Variations of actions of base vehicle (BV) according to the actions of head vehicle (HV) for 302 observations in different rode segments when vehicles were positioned as mentioned in figure1. Low speed and deceleration actions of HV have an influence to the overtaking action of BV

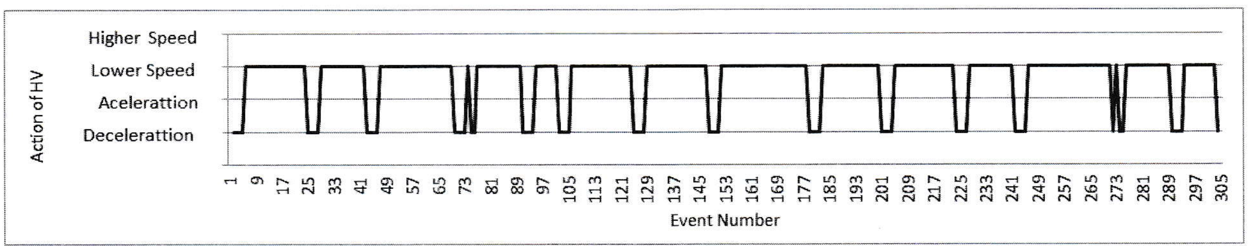


Figure 3 : Variations of actions of BV according to the actions of 2nd HV. There is no significant action of 2nd HV which influenced overtaking action of BV

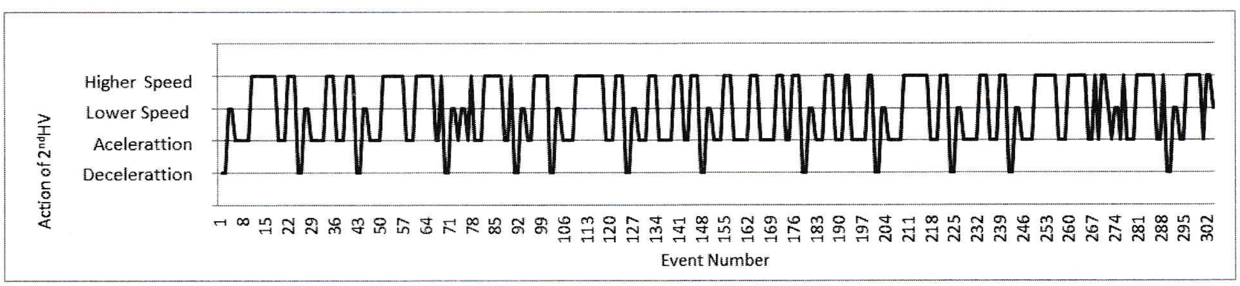


Figure 4 : Variations of actions of BV according to the actions of 3rd HV. There is no significant action of 3rd HV which influenced overtaking action of BV

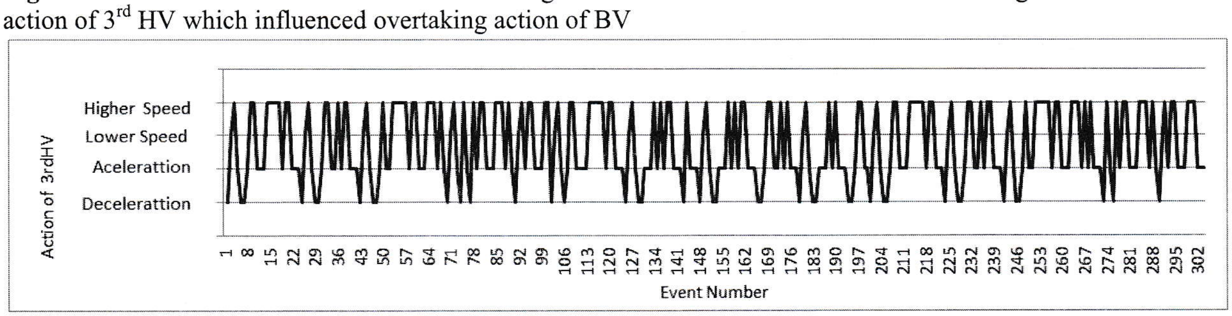


Figure 5 : Variations of actions of base vehicle (BV) according to the actions of rear vehicle (RV). Low speed and deceleration actions of HV have an influence to the overtaking action of BV. There are

spikes in some events because when there is a considerable distance between RV and BV, drivers of BVs tempted to take overtake actions

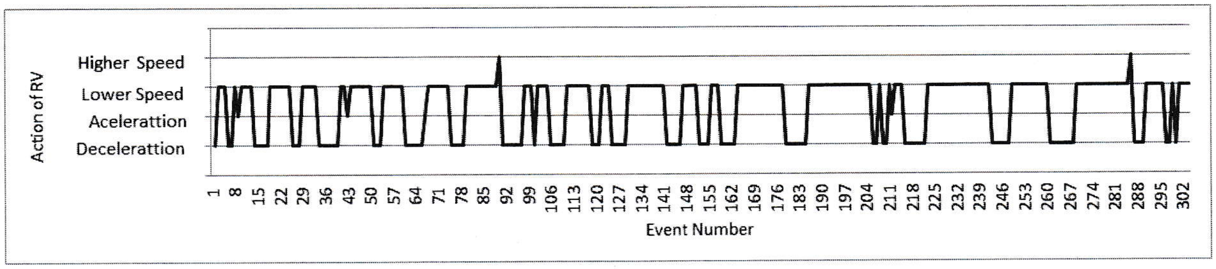
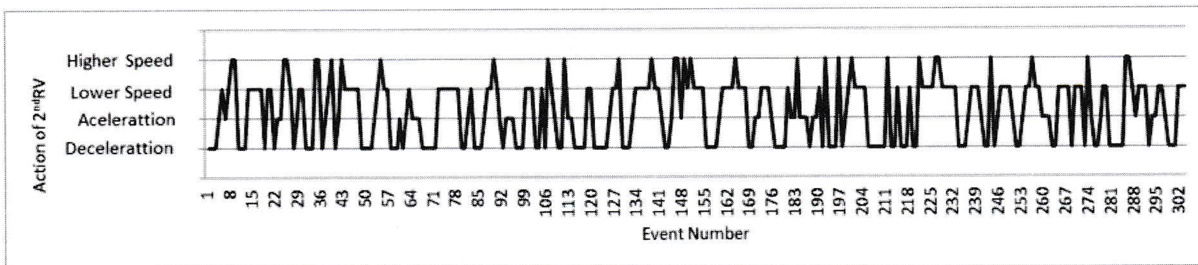


Figure 6 : Variations of actions of BV according to the actions of 2nd RV. There is no significant action of 2nd RV which influenced overtaking action of BV

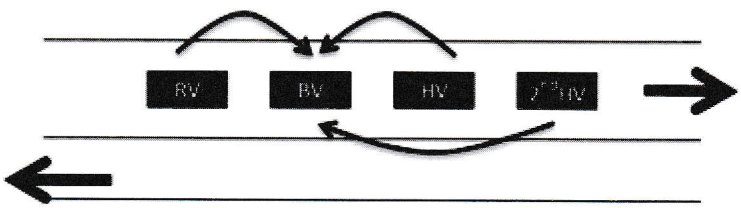


7. Results & Message Passing Approach

Through the analysis of observations, it was possible to identify a relationship for the BV action with immediate head vehicle (HV) and immediate rear vehicle (RV). Figure 2,3 and 4 is for the front end observations and only the graph of HV in Figure 2 has a continuous pattern which only varies between lower speed and deceleration. For the rear end Figure 5 and 6 shows that only RV has the same pattern in Figure 5. According to that only actions of HV and RV have an influence to the action of BV. Likewise by analyzing patterns for acceleration and deceleration, they substantiate that affected reasons for a deceleration action of BV are mainly relatively slower speed of HV and deceleration of HV. BV takes acceleration when HV is accelerating or in a higher speed than the BV. BV takes an overtaking action when HV is in a lower speed of deceleration and further that overtake action is influenced by the action of RV. The driver of BV is tempted to take an overtake action when the RV is in a lower speed or deceleration. There is a high possibility for collisions when taking overtake actions and front and rear end collisions when accelerating and deceleration.

According to the results, to predict a collision, predicting mechanism of BV must be aware of the action of HV, action of RV and itself (BV). Further to be aware of the actions of HV, the system must have the data of 2nd HV. Further the analysis proves that data of 3rdHV and 2ndRV do not have an effect of predicting a collision of BV. Therefore the following model of vehicle positions and message passing approach is applicable by sharing only parameters checked in observations which are position of the vehicle, speed and acceleration or deceleration. GPS location of each vehicle is used to identify the position of each vehicle and using speed parameter, acceleration or deceleration is calculated. By shearing and comparing only GPS location and speed of vehicles one can predict actions of its immediate HV and RV and then collisions possibilities. For one vehicle, creating communication channels with maximum three surrounding vehicle is adequate to predict collisions.

Figure 7 : Proposed model of vehicle positions for message passing when maximum number of vehicles in a single line road segment. The arrows indicate the directions of vehicle motions. RV, BV, HV represents Rear Vehicle, Base Vehicle, and Head Vehicle respectively.



As shown in the Figure 7, in the message passing approach, each vehicle is creating a wireless connection via V2V communication with its HV, 2ndHV, RV and 2ndRV and unicast messages which are having their GPS location and speed to HV, RV and 2nd RV continually as described in Figure 8 and Figure 9. The receiving vehicle compares the data and always aware about the speed, acceleration and deceleration of its HV, 2ndHV and RV to predict movements of HV and RV and itself. Using the prediction algorithm, the vehicle identifies collision possibilities before the driver takes a decision course to a collision. With a change of the position of a vehicle after and overtaking action connecting algorithm reallocates required positions with new vehicles and make the connection. Connecting and predicting algorithm are out of the scope of this paper.

8. Discussion

All the observations were taken for situations where four vehicles were positioned in the road segment to make accurate comparison by maintaining the same environment for all observations. The distances between two vehicles were ignored for the analysis because the main objective of this paper is to identify the model of vehicle positions and influence surrounding vehicles according their position for a driver's decision.

Because all the data was taken in naked eye observations it was difficult to identify speed parameter of 3rdHV relative to the BV. Therefore the 3rd HV observations have quite large uncertainties. But that error did not affect on the final result because BV action always varies on a combination of two parameters like deceleration and lower speed or acceleration and higher speed. Observation errors of identifying low values of accelerations and speed changes are not affected on the results.

9. Conclusion

This paper presented a general model of vehicle positioning on straight road segment which provides minimum connections via a vehicular network to pass messages which are having local parameters of a vehicle namely GPS location and speed. The proposed model can be used to construct vehicular communication network for sharing information to predict possible collisions in roads. Further, it is more efficient because it creates only four connections with surrounding vehicles and generates less network traffic. Therefore, message delay and the processing time for propagating messages are reduced.

The proposed method makes vehicles intelligent enough to inform the drivers about the surrounding vehicle movements and predict collisions situations to avoid vehicle accidents. This model is developed for four vehicles and it can be applied to most situations having two or more vehicles in a single line. Indicating surrounding vehicle movements will be an advantage for the drivers to avoid collisions when visibility is poor, when there are blind spots, or when the driver is not paying enough attention to the surrounding. Thus, the message passing approach presented in this paper is efficient and adequate to predict possible vehicle collisions in single lane roads to ensure safe traveling.

10. Future Work

As the future work, it is expected to combine the influence of opposite side incoming vehicle in to this approach and to identify minimum distance and occasion which a driver of the BV must be warned about a potential collisions. Further this model will be expanded to multi-lane roads.

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