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A Mechanism for Predicting Lane Change Actions of Automobiles to Avoid Collisions

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Abstract

Sudden lane changes for overtaking are main reasons for many road accidents around the world. These accidents cause damage to valuable human lives and property. This paper describes a method that shares speed and location of surrounding vehicles via a Wi-Fi based vehicular network, and predict lane change action of immediate head vehicle. An algorithm, developed considering data collected observing vehicle movements in a single lane road, is implemented in a single-board computer in order to process and make these predictions. Compared to the similar studies, the method proposed in this paper passes messages with the surrounding vehicles effectively and generate warnings to assist the driver to minimize road accidents caused by lane changes.

Keywords: *Vehicular Network, Collision Prediction, V2V Communication,*

1. Introduction

According to the statistics of road safety authorities, sudden lane changes for overtaking [1] and unexpected driver decisions [2] have become a major reason for vehicle collisions. There are a number of road safety systems already being used by vehicle manufactures [3] 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 could be avoided if the driver was provided warning at least one-half second prior to a collision [4].

Studies have been carried out developing applications, which can communicate with other vehicles on the same road-segment to propagate warning messages about a collision. Main focus of most of these studies is detecting 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 occur. 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.

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 [5]. Transmission range theoretically in DSRC standard is 1000 m and the data rate can change from 6 Mbps to 27 Mbps [6]. In vehicular ad-hoc networks, vehicles are converted into wireless mobile nodes and routers to create a network with a wide range approximately up to 350 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 [7]. Further in IEEE 802.11p,

vehicles do not send any acknowledgement for the broad-casted packets. Therefore, the transmitting vehicle may not have any track about the warning message failures. This is a serious problem in collision warning applications where all vehicles behind the accident have to receive the warning message successfully in a short time to avoid chain collisions [8]. In order to handle these issues, in this paper we propose a novel collision warning method to avoid accidents in lane change and overtaking of automobiles. In this method, base vehicle frequently monitors the positions and speeds of surrounding vehicles through a vehicular Wi-Fi network. We have developed an algorithm to predict possible collisions using the position and speed information of the surrounding vehicles. A processing node placed at the base vehicle processes the information received by the surrounding vehicles and generates warnings to avoid possible collisions. This method is applicable to multilane roads and the drive gets quick warnings to avoid possible collisions due to lane change and overtaking.

The paper is organized as follows. Section 2 presents a brief summary of similar studies and the methodology is covered in section 3. Results and discussion is given in section 4, and finally the conclusion is presented in section 5.

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2. Literature review

There are number of good developments have been done in the field of vehicular collision avoidance. Emergency Electronic Brake Light (EEBL) is one application which generates a message when the driver applies brakes to decelerate the vehicle and sends the message to surrounding vehicles via V2V communication. Receiving vehicle determines the relevance of the event and, if necessary, warns the driver [9]. Garrick et.al [10] describe a Forward-collision warning (FCW) system. This application warns the driver about collisions with head on vehicle when two vehicles are in the same lane and same direction of travel. These developments use radar signals to detect other vehicles and then use vehicular communication network to spread the warning message.

Another collision predicting method, closed to an intersection, is described in [11]. Intersection-Movement Assist (IMA) was the result which is designed to avoid collations in road intersections by warning the drivers when it is not safe to enter a junction. In this research a DSRC communication protocols were used to propagate GPS locations of vehicles to warn the drivers when two vehicles are getting closer to each other in an intersection.

Development of a vehicular safety application call Control Loss Warning (CLW) is discussed in [12]. In this application, when a vehicle detects a control loss situation of itself it broadcasts a warning message to remote vehicles. The remote vehicle warns the driver by determining the relevancy of the message. In all developments and researches it has been focused on detecting obstacles or emergency situations and then propagate warning messages. This paper describes a prediction base method to warn the drivers about sudden lane changes which can course a collision.

3. Methodology

The methodology used to develop this approach contained four phases namely preparation, development of message passing approach, data analysis and algorithm development and implementation of predicting mechanism.

3.1 Preparation

In order to develop a model of driver decisions, the vehicle behaviors and traffic patterns in real situations were observed. In this study, 24 single lane straight road segments which have similar environmental conditions but different traffic densities, were observed through naked eye view. All the points were observed for 6 hours by considering four vehicles in a line as shown in Figure 1, and sudden vehicle movements were recorded by comparing one vehicle to its front and rear vehicle. In the Figure 1, RV, BV, HV represents Rear Vehicle, Base Vehicle, and Head Vehicle respectively. The front arrow indicates the directions of vehicle motion. Arc indicates the direction of messages received by the BV and dotted line represents the connectivity range of the BV.

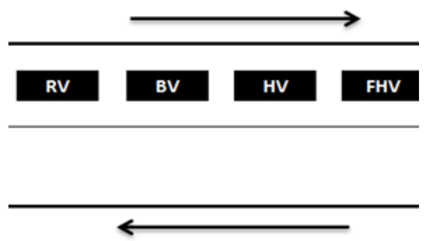

Figure 1. Considered vehicle positions RV – Rear Vehicle, BV – Base Vehicle, HV – Head Vehicle, FHV – Front Head Vehicle. For the naked eye observation above positions of vehicles were considered.

Relative accelerations, relative speeds and relative positions of vehicles were recorded when one vehicle changed the lane for an overtake. Relative differences of speed and acceleration between the time of overtake and previous was analyzed. With the results, it was possible to develop a logical model for driver decisions which contains combinations of relative speed and acceleration change which may cause to make an unexpected event by the driver [13]. Base on that logical model message passing approach is developed.

3.2 Message Passing Approach

To develop the message passing approach, the data recorded from the preparation was further analyzed by considering vehicle positions. The purpose of this phase was to identify the influence of surrounding vehicles to make a significant change in driving behavior of a vehicle. Through that, it was able to identify minimum connections to be stablished with surrounding vehicles and parameters to be exchanged in order to predict an unexpected event of a moving vehicle.

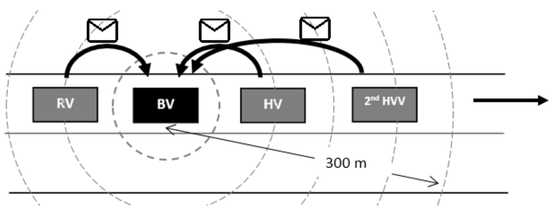

Figure 2. Proposed model of vehicle positions for message passing when maximum number of vehicles in a single line road segment. RV, BV, HV represents Rear Vehicle, Base Vehicle, and Head Vehicle respectively. The front arrow indicates the directions of vehicle motion. Arc arrows indicates the direction of messages received by the BV and dotted line represents the connectivity range of the BV

In the developed approach, all vehicles broadcast its GPS coordinates and speed to the other vehicles but as shown in the Figure 02 the BV accepts messages only from its HV, 2nd HV and RV. To identify the three vehicles GPS data in each message is compared with own location. Nearest two vehicles from front will be taken as HV and 2nd HV. The nearest vehicle from back will be accepted as the RV. The BV listens to the speed changes of accepted vehicles and predicts sudden movements of its RV and HV by comparing RV with BV and HV with 2nd HV. The main reason for considering only limited vehicles results in fast communication between vehicles due to less traffic. Furthermore, it helps to minimize packet loss.

3.3 Data Analysis and Algorithm Development

A sample of one hundred thousand incidents that two vehicles were running on a straight road as one followed by the other (RV and BV), were generated via the PVT Visum, vehicle traffic simulator which is a product of Planung Transport Verkehr(PTV), a German software company. Speed of both vehicles were recorded in each 20 milliseconds for a period of 2 seconds just after the distance between two vehicles was 300m or new vehicle appeared behind the considered vehicle (HV) within 300m. By considering the maximum distance of two vehicles to achieve a packet rate of 10 packets/s, the threshold value of the distance between two vehicles was taken as 300 m [8]. Speeds were measured in Kmh^{-1}. The difference between average speeds of BV and HV was recorded for each 20 milliseconds. The sample was selected by taking speed differences of two vehicles in a time period of 2 seconds when the overtake happens and just before the overtake. Recorded overtakes and non-overtakes for each speed difference were analyzed to develop the prediction algorithm.

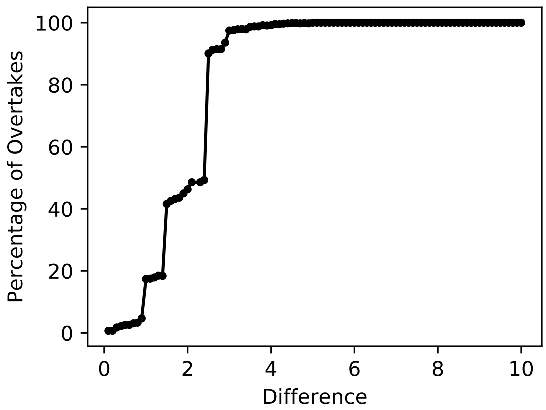

Figure 3. The dotes represents the percentage of overtakes happened for each speed difference between two vehicles within 300m. According to the graph, it is possible to identify four levels of overtaking possibility. 0-1.5 low possibility of overtake, 1.6-2.5 average possibility, 2.6-5.0 high possibility of overtakes and 5.0 and above exact overtake.

3.4 Algorithm Development and Implementation

A prototype (vehicle nodes) was developed using Raspberry Pi single board computer equipped with a GPS receiver as shown in Figure 4. Initial vehicular network was formed to connect all vehicle nodes within the WiFi range and broadcast own GPS coordinates and speed of each node.

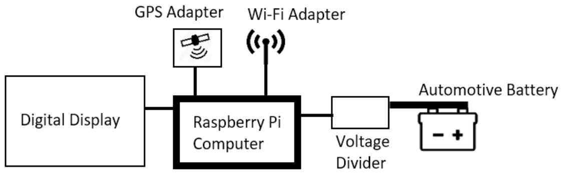

Figure 4. Block diagram of the prototype vehicle node.

In the prediction, algorithm one vehicle node preforms a location comparison test to identify its HV,2nd HV and RV just after receiving a message. The node will accept messages from only three or less vehicles in the positions of HV. 2nd HV and RV and within maximum 300m of distance. With relevant to the highly dynamic changes in vehicle distances the BV records speeds of each position respectively. Each vehicle compares speeds of its 2ndHV and HV to predict the next movement of its immediate head vehicle (HV) and compares its own speed and RV speed to predict taking over actions of immediate rear vehicle (RV). The probability of overtaking will be given in four levels as low, average, high and exact according to the significant stages of overtaking percentages shown in Figure 3. Speed difference 0 – 1.5 low possibility of overtaking, 1.6 – 2.5 average, 26- 5.00 high and 5 or above exact overtake.

Through the analysis and basic testing, functional prediction mechanism was developed upon the following algorithm.

Algorithm 1: Updating algorithm

1. *Receive a message*
2. *Compare GPS coordinates with BV*
3. *Identify vehicle is in front or behind*
4. *If front vehicle*
5. *Compare GPS coordinates with BV and HV*
6. *Identify nearest HV and 2nd HV*
7. *If behind vehicle*
8. *Compare GPS coordinates with BV*
9. *Identify nearest RV*
10. *Update speeds of RV, HV and 2nd HV*

Algorithm2: Prediction Algorithm

1. *Compare speeds of BV and HV*
2. *If BV is to overtake HV*
3. *Compare speeds of BV and RV*
4. *Identify possibility of RV overtaking BV*
5. *Compare speeds of HV and 2ndHV*
6. *Identify possibility of HV overtaking 2nd HV*
7. *Identify risk of overtaking HV*
8. *Indicate risk from RV or HV*

4. Results and Discussion

The developed algorithm was implemented in a general computer and it was tested with manually fed data. The mechanism indicates probability of overtaking BV by RV as low, average, high and exact. Similar to that probability of overtaking 2nd HV by HV also indicates separately. The algorithm was coded into the prototype described in Figure 4, in order to develop Lane Change Prediction Mechanism. The mechanism is applicable for highly dynamic environment because it frequently updates two simple tables with four variables in each namely RV, BV, HV and 2ndHV. Tables are updated with each received message. To maintain the consistency of data during any packet loss, tables will be updated with a calculated value according to the acceleration of vehicles.

5. Conclusions

Unexpected lane changes for overtaking have become a major reason for most of the vehicle accidents. Most of road safety applications focus on detecting obstacles and warning of possible collisions. In this paper, we described a novel method to warn the driver to avoid possible collisions, processing the GPS positions and speed information of the surrounding vehicles (front and rear vehicles in a single lane) through a vehicular Wi-Fi network. A prototype processing node, consists with a Rasberi Pi signal board computer, GPS and Wi-Fi modules, transmits information between the vehicles to processes and generates warnings to drivers. This system generates warnings about sudden lane change, which is the most common reason for accidents. The model discussed in this paper concerned four vehicles drive toward one direction in a single lane. Warnings generated by using the movements of the front and rear vehicles help the driver to drive the vehicle safely. It is critically important in situations like visibility is poor, when there are blind spots, when there are no signal light indications, and when the driver is not paying enough attention to the surrounding. The method described in this paper can be extended to all surrounding vehicles in multilane roads to minimize accidents.

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