A Collision Avoidance Achievement of Vehicle Warning System in Intersection via DSRC

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Abstract: Many accidents were happened because of fast driving, habitual working overtime or tired spirit, moreover, more and more people are also interested in driving safety. This paper presents a solution to enhance intersection safety for adjacent vehicles driving using vehicular communication and developed algorithm. The developed system integrates dedicated short range communication (DSRC) and global position system (GPS) with embedded system into a delicate remote warning system. The proposed system has four mainly components, including positioning unit, communication unit, vehicular date unit and embedded platform in each vehicle. To transmit the vehicular information and broadcast vehicle position, DSRC communication technology is adopt as communication channel. The positioning unit is utilized to provide the position and heading information from commercial GPS module, and furthermore the vehicular data unit is used to receive the break signal, throttle signal, and other signals via controller area network (CAN) interface connected to each mechanism. The CAN module is based on the broadcast communication mechanism which is achieved by using a message oriented transmission protocol. These vehicular signals are held and processed by CAN module in operation platform. All of the communication, positioning and vehicular units are built with an embedded system using IXP processor in Linux operating system, and each unit is managed and processed by embedded platform. From position and vehicular information, this paper provided a conflict detection algorithm to do time separation and remote warning with error bubble consideration. The proposed system is carried out with theoretical algorithm and hardware integration, and the result shows collision avoidance applicability in intersection.

Keywords: Collision Avoidance, DSRC, CAN, GPS

I. INTRODUCTION

In recent years, the number of fatalities in traffic injuries is about nearly 43 thousands according to U.S. department of transportation (DoT) statistic data and the incapacity for work of over 3 consecutive days is about 3.2 million. In Taiwan, there are about four thousand body counts of each year in traffic incident. It is almost sixty percent accidents in intersection. To solve this kind of problem, such as intelligent transportation systems (ITS) and telematics concept, are the most popular method to implement at present traffic problems with the increase of people and vehicles all over the world. Telematics which contains telecommunication and informatics technologies is the most popular area which has many advanced concepts in assist systems in vehicular devices.

In the recent two decades, wireless communication had a tremendous growth in many applications. Cellular systems, infrared, Bluetooth and DSRC in wide area or local area communication have rapidly increased [1]. A general vehicular communication which depends on its coverage area can be classified into four categories: inter-vehicle, outer-vehicle, vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V). In outer-communication, mobile communication has presented its wide coverage, high reliability of data transmission in surveillance applications. The application of data reporting for surveillance or real time control is a rising demand where either GSM or GPRS services are available. However, mobile communication has a drawback in time delay about 1.0 sec in TCP mode or 0.8 sec in UDP mode. DSRC theoretically provides up to 1 km range and allows communications between vehicles moving up to 160 km/h. It also has low latency about 50 millisecond [2]. To meet a higher vehicle safety, DSRC which is a wireless communication protocol in the 5.9 GHz frequency band plays an important role of vehicular system.

GPS is a worldwide converge system that provides high accuracy position, any weather condition and has the advantage in faster positioning. Positioning accuracy and reliability is great concern to many users, and becomes a good engineering topic for study in depth. In this implementation, GPS module is taken to receive positioning data under driving.

This paper proposed a system configuration using an embedded system to operate as a control system to manipulate DSRC unit, CAN unit and GPS unit for collision avoidance. The test information is debugged and showed in the screen of laptop using well defined format, and the total lengths is about 8 bytes with its id in different devices.

II. SYSTEM DESCRIPTION

The system technology for collision avoidance warning system is designed with an integration of GPS and data transmitting through DSRC, as shown in Fig. 1. The information may display on the debugged screen to monitor other neighbor vehicles in remote time operation. The vehicular data of vehicle will be routed and broadcast to neighbor vehicles by short message protocol onto the internet via DSRC communication. A data fusion of collision avoidance warning system platform is built of the basic three parts, including GPS receiver, DSRC communication unit and CAN module. To fulfill the proposed anti-collision application, GPS data as well as vehicular data are processed in specific logic, digital formats and sent through DSRC module in controlled intervals.

In DSRC software, the network protocol is based on IEEE 802.11p standard under open system interconnection (OSI) model. This layer are ported from revising 802.11a, and other layers are followed the TCP/IP modes. In the network interface layer, the DSRC adopts the non-IP or IP base protocol to establish network connection without security or 1609.X.

In GPS module, the output adopts the NMEA-0183 standards as a format for interfacing marine electronic devices. The default communication parameters for NMEA output rate support fixed baud rate at 9600 bits/sec with 8 data bits, 1 stop bit, and no parity. The GPS fixed data is processed in one second period, including the acquisition of position, ground speed and heading.

In vehicular information, the break and throttle condition are transmitted to other vehicles by CAN acquisition. CAN is a serial, asynchronous, multi-master communication protocol for connecting electronic control modules, sensors and actuators in automotive and industrial applications. The CAN-based system is based on the broadcast communication mechanism which is achieved by using a message oriented transmission protocol and different id number.

Fig. 1 System architecture

III. SYSTEM ALGORITHM

The onboard embedded system had mainly two tasks, including receiving neighboring vehicle's GPS data and calculating collision relation. The first task meant that the rover system would process the NMEA data and get the required data. The GPS fixed data (GPGGA) and GPRMC are adopted in this research, including the acquisition of position, ground speed and its course. Based on the acquired GPS data, the on-line display would be mapped into demonstrated map. The second task was collision detection which transforms vehicular coordinate frame from WGS-84 to north-east-down (NED) local navigation coordinate, and gets longitudinal and latitude collision times.

1. Geometry Analysis

Although GPS receiver supplies precision position under dependent performance, the output data of GPS receiver provides lower bandwidth and risks under interference and error. The error factor is considered by reason of GPS error uncertainty. As shown in Fig. 2, B is the ownership so it has an error bubble around it [3]. A is the intruder which drives near the vehicle B in any intersection. Their extrapolation lines have an intersection in the near future. A is positioned at (Λ_1,λ_1) in WGS-84 and travels with its speed V_A. B is positioned at (Λ_0,λ_0) and travels with its speed V_B.

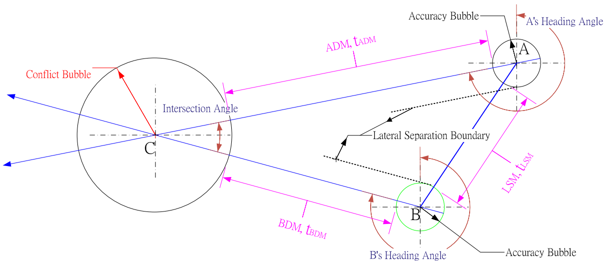

Fig.2. Geometry model of two conflicting objects

L_A and L_B are two line segments which predict future driving trajectory, and the driving distance is decided by initial position and heading. Through two forecasted extrapolation lines, any two vehicles on a planar motion can possibly extrapolate to an intersecting point C and can respectively decide the collision time which two vehicles arrive in point C. The predicted time (t) is an index which decides them whether approaching in the future. Generally speaking, two vehicles will cause conflict or collision when (Λ,λ,t) are all the same, as long as one of them is different, the dangerous condition can be avoided. The time must be observed whether being equal or not.

In conflict analysis, the rough calculation could calculate the relative distance first. If the relative distance is calculated under safe separation and maybe resulted of conflict collision, that needs delicate calculation and does three procedures which includes coordinate transform, geometry distance and collision time.

The first procedure is transformed from WGS-84 to ECEF and ECEF to NED frame using (1)-(2). The altitude (h) is given by GPGGA format from GPS receiver and the other parameters are eccentric (e) and semi-major axis (a). Equation (1) is result from the shape of the Earth which is an ellipsoid, not a true sphere. The following procedure is to take ownership as center and calculate relative position using (2).

$$\begin{bmatrix} x^E \\ y^E \\ z^E \end{bmatrix} = \begin{bmatrix} (N+h)\cos\Lambda\cos\lambda \\ (N+h)\cos\Lambda\sin\lambda \\ [N(1-e^2)+h]\sin\Lambda \end{bmatrix} \quad N = \frac{a}{\sqrt{1-e^2\sin^2\Lambda}} \tag{1}$$

$$\begin{bmatrix} x^N \\ y^E \\ z^D \end{bmatrix} = \begin{bmatrix} -C(\lambda_0)\cdot S(\Lambda_0) & -S(\lambda_0)\cdot S(\Lambda_0) & C(\Lambda_0) \\ -\sin(\lambda_0) & \sin(\lambda_0) & 0 \\ -C(\lambda_0)C(\Lambda_0) & -S(\lambda_0)C(\Lambda_0) & -S(\Lambda_0) \end{bmatrix} \times \begin{bmatrix} x_1^E - x_0^E \\ y_1^E - y_0^E \\ z_1^E - z_0^E \end{bmatrix} \tag{2}$$

Although the mathematical model usually adopts Cartesian coordinate, all of the angles are still referenced to NED coordinate. Fig. 2 only shows one kind of collision condition, but vehicle A maybe locates at different quadrant and has different heading angle result from geometry relationship. The collision conditions are discussed and suitable at any conflict area, and each possible case is listed in the following Table I(A) & I(B). In Table I, the global heading angle is (H_A,H_B) and local relative heading is (H_{AB},H_{BA}). The local relative heading (H_{AB}) takes B as center and could be given relative to North direction.

Table 1. Relative heading angle in Quad I&IV

	Case I	Case II	Case III	Case IV
∠A	$2\pi-H_{BA}+H_A$	$H_{BA}-H_A$	H_A-H_{BA}	H_A-H_{BA}
∠B	$H_{AB}-H_B$	H_B-H_{AB}	$H_{AB}-H_B$	$2\pi+H_{AB}-H_B$

Table 2. Relative heading angle in Quad II&III

	Case V	Case VI	Case VII	Case VIII
∠A	$H_{BA}-H_A$	H_A-H_{BA}	$H_{BA}-H_A$	$2\pi-H_A+H_{BA}$
∠B	$2\pi-H_{AB}+H_B$	$H_{AB}-H_B$	H_B-H_{AB}	H_B-H_{AB}

2. Collision Time Calculation

According to the pervious segment, the possible intersection is calculated and needs to forecast in time by considering the possible errors. This paper proposes a simplified computation that the possible ADM does plus and subtraction operations using (4) in vehicle A, moreover, the same concern is considered in own vehicle. The error is distributed over the circle whose magnitude of radius is changed by different GPS. One sigma error of commercial GPS is about 7 meters. In this paper, the circle error is known as the error intersecting bubble as shown in Fig.2. And it is also distributed over the driver response time whose magnitude is about 0.5 to 0.75 sec [4]

After the embedded processor calculates the ADM and BDM, both of regional collision times (t_{A1}, t_{A2}, t_{B1}, t_{B2}) are given by using (4). If the temporal separation between two vehicles is larger than zero, the time is no overlapping, it represents there is no significant intersection between them. It predicts there is no dangerous conflict in the near future, as shown in right Fig. 3. If $t_{A1\text{-}A2}$ occurs between the start of t_{B1} and the end of t_{B2}, the time range are overlapping in left Fig. 3. This represents a conflict or intersection. This condition can estimate that there will be an approaching incident in the near future, and then the collision time will be showed in the screen and given some sound by collision avoidance system.

After the coordinate is located in navigation frame in Eq.(2), the screen display needed to transform into vehicle coordinate, as shown in Fig. 4. And the transform matrix is Eq.(3). The right vector is NED position and H is the vehicle heading relative to earth pole. After the matrix multiplication, the left term in Eq.(3) is screen coordinate.

$$t_{A1} = (\mathrm{ADM} + \mathrm{error\ \ range}) / V_A, \quad t_{A2} = (\mathrm{ADM} - \mathrm{error\ \ range}) / V_A \tag{3}$$

$$\begin{bmatrix} B_x \\ B_y \end{bmatrix} = \begin{bmatrix} \cos(H) & -\sin(H) \\ \sin(H) & \cos(H) \end{bmatrix} \begin{bmatrix} E \\ N \end{bmatrix} \tag{4}$$

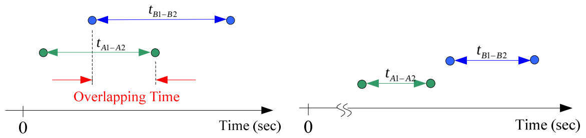

Fig. 3 A span overlapping time and opposite condition

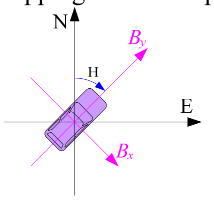

Fig. 4 Navigation coordinate to vehicle one

IV. SYSTEM IMPLEMENTATION

The test platform, as shown in Fig. 5, was used to implement the proposed on-line display system. Two vehicles were used to run on the ARTC roadway to verify the collision warning function; while two vehicles were followed on the road or driven to an intersection in order to easily verify system design in the verification. Under system design and implementation, vehicular data which connected to CAN interface was collected for scheduled tests. For test operations, DSRC module was used to do two-way data link communication. The embedded system used two DSRC modules to do data communication in control channel and service channel individually. The GPS receiver also outputted positioning data, and the positioning performance was well processed and mapped to demonstrated map.

Fig. 6 showed the on-line display test, where two vehicles were running on ARTC roadway. The test demonstrated the display system in a longer distance, and the driver drove along with preceding vehicle. Fig. 7 showed another test, where the driver drove into an intersection. Two cases offered an important awareness to the driver under test. The map reported neighbor vehicle positioning data about 1 second periodically, and broadcasted to other vehicle via DSRC. In these tests, the actual position of the vehicle was monitored and displayed on the screen. Although GPS error is inevitable, it is not a problem in this paper with error bubble consideration. The driver could easily see how other vehicle was presented in the digital ARTC map. The embedded processor predicted that there was possible danger in the near future. The display showed others position and speed signal of mapped vehicle that the operator could be fully aware of other vehicle situation under proposed system concept.

Fig. 5 System hardware and implementation


Fig. 6 Car following with safe distance (state=1)


Fig. 7 Running into intersection (warning state=3)

VI. CONCLUSION

In this paper, the availability of on-line display system using GPS positioning is verified and the vehicle data is allowed on-line data exchange through DSRC module. The proposed warning system assists drivers to know current relationship to other vehicles through intersection and following tests with the situation awareness capability.

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