Implementation of Radar Map Using GPS in Vehicular Networks

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Abstract. In the highway environment, many applications require localization. It is common to use the Global Positioning System (GPS) to find the current position, but GPS is easily influenced by the external environment and has many internal errors. Dead Reckoning (DR) is a common method for correcting the GPS position. However, the related applications do not have a notice system that can show the number of and distances to neighboring vehicles. In this paper, we design a map application on the Android operating system for vehicular networks. In this map application, the road map would be shown on a monitor, and the neighboring vehicles could also be drawn on this map. Users can easily understand the road conditions. Moreover, the application can exchange traffic information with other vehicles, and the map can also show the vehicles which are out of range. Furthermore, the application can show the time to collision between two vehicles. The experimental results will show the adjustment of position corrected by DR on Google Map, and the radar map on the Android operating system.

1 Introduction

With the deployment of Dedicated Short-Range Communications (DSRC) and wireless technologies such as 802.11p, a vehicle can exchange traffic information with other vehicles through wireless communication and form a vehicular network [1]–[3]. When you have lost your way, location is quite important and will usually be obtained through Global Positioning System (GPS) equipment. GPS equipment, through the use of satellites as reference positions, provides absolute vehicle positions. But its accuracy and availability are affected by the satellite geometry, selective availability, environmental effects, and propagation delay through the ionosphere or any other complex unknown factors [4]–[6].

The Dead Reckoning (DR) method is an often used vehicle positioning technique [7]–[9]. In this method, heading and distance sensors are used to measure the displacement vectors, which are then used in a recursive manner to determine the current

R.-S. Chang et al. (Eds.): *Advances in Intelligent Systems & Applications*, SIST 20, pp. 663–672.
DOI: 10.1007/978-3-642-35452-6_67

vehicle position. However, the accuracy of the DR method constantly degrades over time, since the errors in the measurements accumulate and affect the current position estimation. For vehicles travelling on a road network, the map-matching technique is often used to correct positioning errors. In this method, the vehicle's travelling path is constantly compared with the road network. Through the matching process, the most likely location of the vehicle with respect to the map is determined. Several papers devoted to achieving accuracy in vehicle positioning have integrated GPS and DR, and applied this with the map-matching technique. The estimation of the actual vehicle location from the GPS position together with the use of the road information contained in the digital map using the spatial relationship between the GPS position and the roads has performed well [10]. However, there is as yet no application which is able to show the distance between two vehicles using the idea of a radar map which is constantly displayed: it is hard for the existing methods to draw locations and distances accurately on a map since the GPS is always jumping and the error is about 5–10 meters.

The present paper proposes a radar map based on the Android operating system, one which is able to show the locations of the neighboring vehicles in the vehicular network. The speed and heading information from the National Marine Electronics Association (NMEA) are used to minimize the GPS measurement errors which may result from signal noise or changes in the satellite geometry. Hence, in addition to providing the relative distance between other vehicles, an adaptive correction algorithm is proposed to minimize the cumulative position errors. Moreover, the warning of time to collision (TTC) is very important for the driver. The application, on the Android operating system, can show the TTC between two vehicles. In the experimental results presented, the radar map shows the neighboring vehicles, and this helps decrease the chances of a car accident due to dead line of sight.

The remainder of this paper is organized as follows. In Section 2, we present the implementation of our radar map. The experimental results and performance evaluations are given in Section 3. The conclusions are given in Section 4.

2 The Implementation of the Radar Map System

2.1 The Industrial Technology Research Institute's WAVE/DSRC Communications Unit (IWCU)

The Industrial Technology Research Institute (ITRI) WAVE/DSRC Communications Unit (IWCU) [11] is an integrated wireless communication system designed for deploying Intelligent Transportation System (ITS) applications and improving traffic safety on roadways, and is shown in Fig. 1. The IWCU device not only supports the IEEE 801.11p/1609 standard but also integrates the 3G and Wi-Fi protocols. With these capabilities, it can support many different types of communications, including intra-vehicle, vehicle-to-vehicle (V2V), and vehicle-to-roadside (V2R), and can support additional vehicle-to-infrastructure (V2I) communications. The IWCU device

Fig. 1. ITRI WAVE/DSRC communication unit

also provides measurements of the GPS, such as the heading and speed of a vehicle. Moreover, the IWCU also provides a software development kit (SDK). Using the SDK tools, many ITS applications can be developed easily on the flexible open platform.

2.2 Dead Reckoning

On a two-dimensional planar space for vehicular travel, it is possible to calculate a vehicle's position at any time, provided that the starting location and all subsequent displacement vectors are available. The DR method is a popular technique. The equation of the vehicle's position (x_k, y_k) at time t_k can be expressed by

$$x_k = x_0 + \sum_{i=0}^{k-1} s_i \cos\theta_i\,, y_k = y_0 + \sum_{i=0}^{k-1} s_i \sin\theta_i \tag{1}$$

where (x_0, y_0) is the initial vehicle location at time t_0, and s_i and θ_i are, respectively, the length and the absolute heading of the displacement vector from the vehicle's position (x_i, y_i) at time t_i to (x_{i+1}, y_{i+1}) at time t_{i+1}. In Fig. 3, the relative heading is defined as the difference between the absolute headings at two consecutive instances and is denoted by ω_i. Given the relative heading measurements ω_i for time $t_0, t_1, \ldots, t_k$ the absolute heading of the vehicle θ_k, at time t_k, can be calculated from $\theta_k = \sum_{i=0}^{k} \omega_i$. As shown in Equation (1), the dead reckoning method is a cumulative process. Consequently, all previous sensor errors will be accumulated, and this decreases the accuracy of the current calculated position. As we all know,

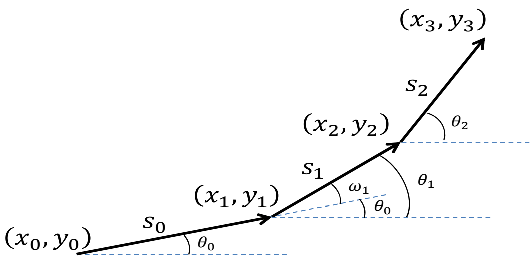

Fig. 2. Dead reckoning method

GPS often jumps because of multipath interference and changes in the satellite constellation. The calculation is accompanied by greater errors as time passes. The gap between the current position and the estimated position will be greater when a small error is included in the calculated heading and the mileage. Many researchers use the DR method when the GPS signal is cut off. However, we use the speed and heading information from the GPS to implement the DR method in this paper.

2.3 GPS

The Global Positioning System (GPS) is a satellite based radio navigation system realized by the U.S. Department of Defense [12]. When the GPS is fully operational, there will be a constellation of 24 Navstar satellites in six orbital planes. The satellite orbits will be arranged so that a minimum of 5 satellites are visible to the user anywhere in the world at all times. Whether 2-dimensional or 3-dimensional navigations, the GPS receiver selects a set of at least 3 or 4 satellites that forms the best satellite geometry, and calculates the distances between the receiver and the satellites. Given these distance measurements, the user's position with respect to the earth's inertial coordinates can be obtained [13]. However, it also possesses unexpected effects: large position errors may cause the GPS position received in the receiver to be inaccurate when the GPS satellite geometry and visibility are less than perfect. For road vehicles that constantly travel in urban areas where tunnels, overpasses, tall buildings, and trees are abundant, perfect reception conditions are rarely possible. Even when there are enough satellites available for the position calculation, the satellite geometry may not be good enough to obtain an accurate position.

2.4 Error Revision

It has become clear that a superior positioning system can be obtained if the advantages of the dead reckoning system and the GPS can be combined. The absolute positional accuracy of GPS can be used to provide feedback to calibrate the dead reckoning system, while the smoothness of the dead-reckoning signals can be used to correct the errors of the GPS position signals due to multi-path interference or other problems [14]. There have been several approaches that have combined GPS and dead reckoning. This integration is usually done either through a switching algorithm that switches from one system to another if the latter has a better signal condition. In such approaches, the integrated system usually performs as a stand-alone system if either the GPS signal or the dead reckoning signal is absent [15]–[18]. Given the availability and accuracy problems with GPS signals, an integrated system uses dead reckoning as its primary positioning technique. In our designed module, when the GPS signals are available, they will be used not only to correct the drifted dead reckoning position, but also to calibrate the dead reckoning sensors. When the GPS is not functioning well, the calibrated dead reckoning system will provide better performance than before.

2.5 The Implementation of Radar Map

The radar map is designed on the Android system, a Linux-based operating system for mobile devices, such as smartphones and tablet computers. It was developed by the Open Handset Alliance, led by Google. The error revision algorithm is designed in the IWCU SDK, and the system architecture is shown in Fig. 3. When the IWCU receives signals which contain GPS headings and speeds, the error revision will use the dead reckoning algorithm to calibrate any jumping GPS signals. Moreover, the IWCU will send the new position to the Android system through 802.11g. After receiving the new position, the mobile application is designed to transfer the position to a pixel system and plot a radar map in the Android operating system. The experimental evaluation will discuss the difference between the radar map with and without the DR method. The users can input the GPS position in Google Map, which points to the nearest position on the road. In the next section, the experimental evaluation will show the Google Map results and the radar map warning messages on an Android simulation.

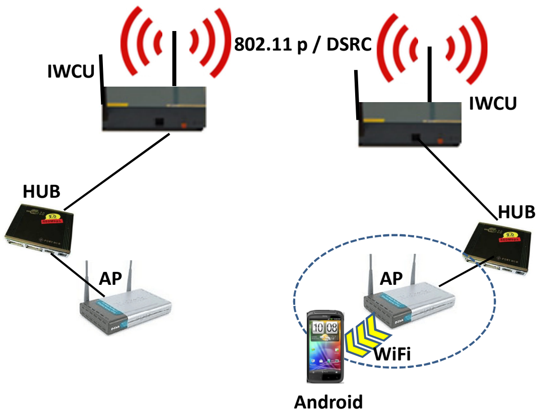

Fig. 3. System architecture

In Fig. 4, the IWCU can get the GPS information, such as latitude, longitude, speed, and heading, every 100 milliseconds. By comparing this with the history of the GPS information, the system will detect whether the GPS is reasonable or not. If the GPS information is not reasonable, the system will use a simple dead reckoning algorithm to adjust it by comparing it with the history of the GPS data, and broadcast the adjusting GPS information to nearby vehicles every 100 milliseconds. After receiving, the IWCU will send the information (including id, latitude, longitude, speed, heading, and time) to the Android system through Wi-Fi. In order to achieve real-time service, the Android system can distinguish who is sending the GPS information by unequal identification, and compute each data by thread. Using the received data, the relative distance (in the Cartesian coordinate system) from the sender to the receiver can be calculated, and the system can translate the suitable scale by the road information. In our experiment, the radar map can be drawn on the Android system in real-time, and the more detailed experimental results will be discussed in the next section. Moreover, in order to discuss the performance of the DR algorithm, the caution function is also implemented in our system. The warning function will notify the driver based on the speed difference, direction, and distance. When a red "Dangerous" is shown on the Android screen, the driver will know that another vehicle is too close. On the other hand, "Safe" means that there is a safe state with respect to the other cars.

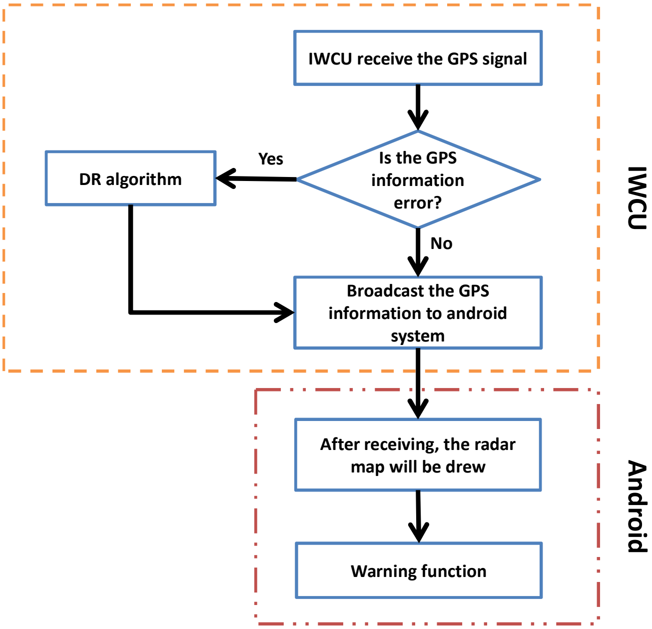

Fig. 4. Flow chart

3 Experimental Evaluation

3.1 Experimental Setup

In Fig. 5, each car (car 1 and car 2) implements the DR method to correct the position error as described in Section 2.2. Each car will broadcast its own GPS information and then the other cars will receive this information to provide a radar map to the driver as described in Section 2.5. The experimental area was in Ximen Rd., Tainan, Taiwan. The average speed of car 1 and car 2 was 35 km/h. The WAVE/DSRC device was the IWCU 3.0 as described in Section 2.1.

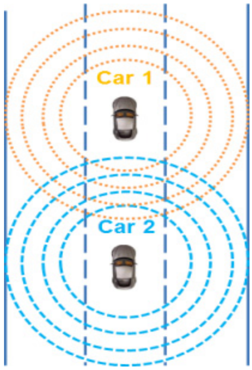

Fig. 5. Experimental topology

Fig. 6. Performance of DR method

3.2 Performance of GPS DR

We present the DR performance in this section. Fig. 6 (a), Fig. 6 (c) and Fig. 6 (e) are without DR. Fig. 6 (b), Fig. 6 (d) and Fig. 6 (f) are with DR. Many researchers have used gyroscope and accelerometer hardware to implement the DR method. In this paper, we used the speed and heading of the GPS information to implement a software DR method. Hence, we based it on the speed and heading from the GPS information to modify the position. We found that the speed and heading of the GPS information can help the GPS position as shown in Fig. 6. We can calculate the distance between two GPS values [19] by website [20]. Hence, we can obtain a DR-enhanced performance as follows. With DR, the position is enhanced 1.8 m, 1.2 m, 2.1 m, 2.5 m, 2.3 m, and 1.7 m, over the position without DR, in Fig. 6.

3.3 Performance of Radar Map

We present the warning message performance in this section. The cars A and B are the same as in Fig. 7. Car A is without DR and car B is with DR. In this scenario, the receiver car always drives in the middle lane and car A (car B) always drives in the right lane. In Fig. 4, “Dangerous” is shown on the Android screen, which means another vehicle is very close. However, car A (without DR) has the wrong GPS information for warning the driver. Hence, the driver (receiver) receives a false alarm. In Fig. 7 (a) and Fig. 7 (b), car A has been very close. In Fig. 7 (c) and Fig. 7 (d), car A has been positioned in another lane.

(a) (b) (c) (d)

Fig. 7. Performance of warning message

4 Conclusions

This paper proposed a map application in the Android operating system. A road map is shown on a monitor and the neighboring vehicles are drawn on this map. Users can easily understand real-time road conditions. The proposed application can exchange traffic information with the other vehicles, hence, the map can also show vehicles which are out of range. Moreover, the proposed application can show the TTC between two vehicles, relying on software dead recknoning (DR). The experimental results have shown that adjusting the GPS position by corrections from DR can enhance the accuracy by from 1.7 m to 2.3 m. Moreover, the proposed radar map can support a collision warning which can avoid false alarms by using the software DR method.

References

1. Fernandez, J., Borries, K., Cheng, L., Kumar, B., Stancil, D., Bai, F.: Performance of the 802.11p physical layer in vehicular-to-vehicular environments. IEEE Transactions on Vehicular Technology 61(1), 3–14 (2012)
2. Hassan, M., Vu, H., Sakurai, T., Andrew, L.: Effect of retransmissions on the performance of the IEEE 802.11 MAC protocol for DSRC. IEEE Transactions on Vehicular Technology 61(1), 22–34 (2012)
3. Hsieh, T., Tseng, Y.: Vehicular traffic information dissemination for WAVE/DSRC networks. In: IEEE International Symposium on Wireless and Pervasive Computing, pp. 1–6 (2011)
4. Alam, N., Balaei, A., Dempster, A.: A DSRC Doppler-based cooperative positioning enhancement for vehicular networks with GPS availability. IEEE Transactions on Vehicular Technology 60(9), 4462–4470 (2010)
5. Lim, H., Chung, T.: Performance evaluation of relative positioning based on low-cost GPS and VANET. In: IEEE International Conference on Internet Technology and Secured Transactions, pp. 542–543 (2011)
6. He, Z., Ma, Y., Tafazolli, R.: Cooperative localization in a distributed base station scenario. In: IEEE Vehicular Technology Conference, pp. 1–5 (2011)
7. Cho, B., Koo, J., Yoon, B., Kim, B.: The research of dead reckoning stabilization algorithm using different kinds of sensors. In: IEEE International Conference on Control, Automation and Systems, pp. 1089–1092 (2010)
8. Yan, Z., Peng, S., Zhou, J., Zu, J., Jia, H.: Research on an improved dead reckoning for AUV navigation. In: IEEE Chinese Control and Decision Conference, pp. 1793–1797 (2010)
9. Fouque, C., Bonnifait, P., Betaille, D.: Enhancement of global vehicle localization using navigable road maps and dead-reckoning. In: IEEE Position, Location and Navigation Symposium, pp. 1286–1291 (2008)
10. Wen, J., Lu, X.: Research on low-cost vehicular integrated navigation. In: IEEE International Conference on Advanced Mechatronic Systems, pp. 287–290 (2011)
11. Li, H., Lin, K.: ITRI WAVE/DSRC communication unit. In: IEEE Vehicular Technology Conference, pp. 1–2 (2010)
12. Shimonaka, Y., Tasaka, S., Hatta, Y., Wada, T., Okada, H.: Accuracy improvement of vehicular collision avoidance support system (VCASS) for the next generation ITS. In: IEEE Wireless Communications and Networking Conference, pp. 2517–2522 (2007)
13. Savasta, S., Pini, M., Marfia, G.: Performance assessment of a commercial GPS receiver for networking applications. In: IEEE Consumer Communications and Networking Conference, pp. 613–617 (2008)

14. Yaacob, N., Abdullah, M., Ismail, M.: Ionospheric modelling: improving the accuracy of differential GPS (dGPS) in equatorial regions. IEEE Asia-Pacific Applied Electromagnetics, 1–5 (2007)
15. Bevly, D., Parkinson, B.: Cascaded Kalman filters for accurate estimation of multiple biases, dead-reckoning navigation, and full state feedback control of ground vehicles. IEEE Transactions on Control Systems Technology 15(2), 199–208 (2007)
16. Berman, Z., Powell, J.: The role of dead reckoning and inertial sensors in future general aviation navigation. In: IEEE Position Location and Navigation Symposium, pp. 510–517 (1998)
17. Krakiwsky, E., Harris, C., Wong, R.: A Kalman filter for integrating dead reckoning, map matching and GPS positioning. In: IEEE Position Location and Navigation Symposium, pp. 39–46 (1988)
18. Yang, Y., Ye, H., Fei, S.: Integrated map-matching algorithm based on fuzzy logic and dead reckoning. In: IEEE International Conference on Control Automation and Systems, pp. 1139–1142 (2010)
19. Kuo, W.: Integration of GPS and dead-reckoning navigation systems. In: IEEE Vehicle Navigation and Information Systems Conference, pp. 635–643 (1991)
20. GPS distance calculate tool, china.cos@gmail.com. this tool is powered by Cosbeta, http://www.storyday.com/wp-content/uploads/2008/09/latlung_dis.html