TOWARD INTELLIGENT CAR NAVIGATION SYSTEM USING VEHICLE TO VEHICLE WIRELESS COMMUNICATION AND VISUAL COMMUNICATIONS

Susumu Ishihara
Graduate School of Science and Technology
Shizuoka University
3-5-1 Johoku, Naka-ku, Hamamatsu 432-8011
Japan
e-mail: ishihara@sys.eng.shizuoka.ac.jp

Abstract

Grasping the current road condition on the route and the intention of the drivers of neighboring vehicles will be useful for safe, ecological and comfortable drive. Vehicle to vehicle network and visual communication using a vehicle-mounted camera are valuable techniques for this purpose. In this paper we present our two target systems using these techniques, Live Picture Car Navigation system and Navigation with Smart Blinkers, then discuss the technical issues for realizing these systems.

Keywords: Vehicle to Vehicle Communication, Ad Hoc Communication, Smart Blinker, Visual Communication,

1. Introduction

Drivers often want to know the condition of their destination locations and intention of the drivers of other cars. "Oh, the right-turn lane is very congested. What's going on beyond the intersection?" "Is that car going to the shopping center? Then, we can follow it." However, today, we do not have any way to know them in real time.

Today many car manufactures and researchers are working on vehicle to vehicle (V2V) communication technology mainly for safety, for example, notifying a road condition beyond a blind corner, approach of an emergency vehicle, sudden braking of the precedent vehicle, etc. Adding to such information for safety, providing live video or picture of drivers' intended area will be useful for drivers to plan their driving route and schedule, avoiding accident and congestion.

We have been developing V2V network technologies toward providing drivers live-video or high definition picture of drivers' intended area. In this paper, we present the overview of the intelligent car navigation system using V2V communication and issues for realizing such a system. Then we show our future plan to develop an intelligent car navigation system using both V2V wireless communications and visual communications. We also present some basic strategies to develop the system from viewpoints of network technology, image processing and visualization especially focusing on smart blinkers, i.e. displays attached on the outside of the body of a vehicle.

2. Intelligent car navigation system using V2V communications

2.1. Pull-based information sharing system on V2V network

The main goal of V2V communication is providing safety and comfort for passengers. Especially, safety is the hottest research area. Informing the existence of imminent danger such and obstacles, a hidden red signal and approaching emergency vehicles using V2V network is one of he typical applications. In such an application, the information is *pushed* from a vehicle which detects a special event such as an accident or detection of an obstacle. If many vehicles send such information simultaneously, the communication media will be congested. Thus the information sent by safety applications has to be selected carefully. Adding to this, due to the urgent need of such information, timeliness and reliability is crucial.

On the other hand, Pull-based systems will be also useful. In such applications, drivers obtain information related to a geographical area such as a congested intersection, a shop etc. by sending queries

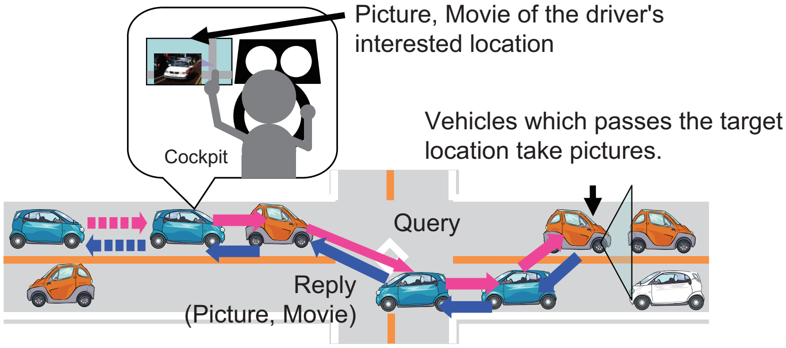

Figure 1: Live picture car navigation system

to the area and receiving reply messages from vehicles near the interested area. Sending messages to a specified location is called *Geocasting*.

We have been working on network technologies which improve the availability of location dependent information such as road condition, a picture of an intersection, advertisement information from road side shops on pull-based information sharing system on V2V network using geocasting. Our main goal is to develop intelligent *visual* car navigation systems using these technologies. We have two target systems. One is *Live Picture Car Navigation system*. Another is *Navigation with Smart Blinkers*.

2.2. Live picture car navigation system

Figure 1 shows the big picture of the live picture car navigation system. The system works as follows. Suppose a driver wonders why only the right turn lane is very long. He or she touches a point near the next intersection on a map displayed on a car navigation system. Then a query message which requests pictures of the intersection is sent to vehicles near the intersection. Supposing cameras attached to vehicles take pictures of the scene in front of each vehicle periodically, if a vehicle receives the query message and it has taken pictures of the intersection, it sends back the pictures to the requesting vehicle. If the requesting vehicle receives the pictures from multiple vehicles, it selects and merges the pictures and display the merged picture.

This application will not require very high timeliness. Instead of timeliness, the quality of the information is expected. Because the communication range of wireless communication is limited, it is difficult to maintain the connectivity between vehicles if the density of them is low. Even if the links between vehicles are intermittent, if users can obtain data which they want, the system is useful. We have developed some schemes to distribute replicas of location dependent information[1][2][3][4] so that users can obtain the distributed location dependent information even when the connectivity between vehicles is low.

We can also use infrastructure-based network for sharing information between vehicles. Today major motorcycle vendors have their own infrastructure based network services. They rely on cellular network. In these systems, the current geographical position of each vehicle obtained by GPS and additional information such as moving speed, on/off status of wipers, etc. are sent to a server on the Internet through the cellular network. Using the collected information, the server analyzes the estimated traveling time, congestion, etc. and sends the results to vehicles using the service.

It is useful to use the Internet for collecting the information of many vehicles in a wide area. However, if the information is used only in a narrow area, the cost and the bandwidth of wireless communication for transmitting the information are wasteful. For example, location dependent information such as a picture of a small intersection may be used only by vehicles which are coming to the intersection. They will not be used by other vehicles. If the size is large, the server has to have very large storage.

On the other hand, if such information is transmitted only to neighboring vehicles using vehicular-to-vehicular network, the bandwidth of the infrastructure-based wireless communication and the storage space of the server will be saved. V2V communication is useful for these purposes.

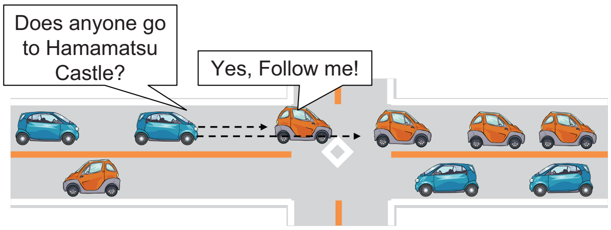

Figure 2: Query to neighboring vehicles which have smart blinkers

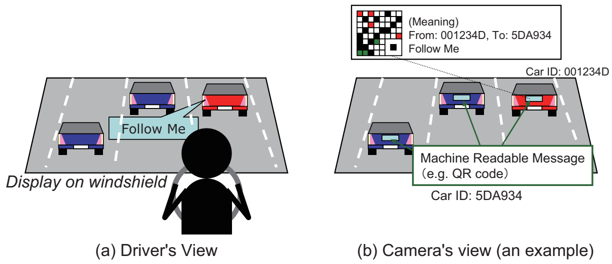

Figure 3: Idenfifying a vehicle using a dynamic 2D marker.

2.3. Navigation with Smart Blinkers

If the road layout is complicated, it is not easy to follow the audio instruction or an arrow displayed on the screen of a car navigation system. Because, the real scene and one imagined by the driver may not the same. If the road on the instructed route is very narrower than expected, the driver may hesitate to follow the instruction. However, if a car driven by a person who knows the route well is leading, it is easy to follow the instruction because the following driver can see the instruction in the real scene.

Smart blinker is a display attached to the back of a vehicle. It is used to show messages from the leading vehicle to the following drivers. The message is human and/or machine readable. **Figure 2** illustrates the use case of smart blinkers. When a driver wants to know whether a vehicle going to the same destination is in the neighborhood, the driver's vehicle sends a query messages to the neighboring vehicles using broadcast or flooding in the V2V network. If a vehicle is going to the same destination — the destination registered to the car navigation system is close to the queried destination or the driver answers manually —, the vehicle sends back a reply message to the requesting vehicle and presents a human and/or machine readable message on the smart blinker so that the driver or the computer system of the requesting vehicle can identify the replying vehicle. The machine readable message may be presented on a 2D marker such as QR code. We suppose the marker consists of LEDs or e-ink and can change the message dynamically.

The machine readable message displayed on the smart blinker will be captured by a camera mounted on the requesting vehicle. Then the requesting vehicle obtains the geographical position of the vehicle and the content of the message. The IDs of the source and the destination of the message are verified by comparing them with a reply message sent through the V2V wireless link. Through this process, machine readable messages which are not sent to the requesting vehicle are omitted.

If the requesting vehicle has a windshield display, the reply message sent to the vehicle will be displayed near the real image of the replying vehicle using augmented reality (AR) technology[5] as shown in **Figure 3**. Even if the requesting vehicle does not have a windshield display, the human readable message will help the driver identify the replying vehicle. The human readable message will be also useful to compensate the positioning error of the machine readable message. Adding to this, the human readable message may be used by drivers of vehicles other than the requesting one. For example, as shown in **Figure 4**, direction messages for popular locations may be useful for many drivers.

3. Technical Issues

3.1. Sharing information in intermittent V2V networks

As stated in 2.2., distributing replicas of location dependent information is useful for improving the availability of the information in intermittent V2V networks because geocast query messages

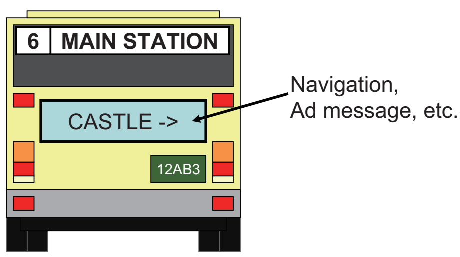

Figure 4: Example of human readable smart blinkers: Dynamic message on the back of a bus.

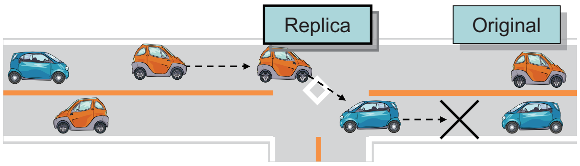

Figure 5: Distributing replicas of location dependent data (or picture, movies) ahead of link disconnection.

may reach to one of the replicas, even if the connectivity of the requesting vehicle and the information generator vehicle (**Figure 5**). In order to improve the "hit ratio" of geocast queries, the replicas of location dependent information should be kept at the original position where the information generated, even if the generator vehicle moves away from the position. One naive approach is that all vehicles periodically broadcast the replicas of location dependent information that each vehicle has. However, this approach consumes the wireless communication bandwidth drastically and may cause losses of emergency messages and beacon messages used for notifying the current position of each vehicle, especially at congested intersections.

Our RD scheme (Road-aware Direction based replica distribution scheme)[4] is designed to mitigate the congestion caused by replica distribution traffic. In the RD scheme, vehicle which has generated a location dependent data at a position broadcasts the replica at the next encountered intersection because many vehicles will be at intersections and they can receive the replica sent at a time. Before broadcasting the replica, the data generating vehicle checks the moving direction of neighboring vehicles and chooses one vehicle for each moving direction so that the data generating vehicle can assign them the next replica distribution at the different intersections. The chosen vehicles broadcast the replica at the next encountered intersections. Adding to this, the RD scheme has a mechanism for canceling redundant replica distribution according to the list of replicas which each node has and the last timing of the distribution of the replicas of the same data. This mechanism avoids collisions of broadcast messages at intersections.

Distribution of Large Data Even the RD scheme reduces traffic at intersections, if the data size is large and they need multiple packets for transmission, collisions may occur. If live picture or movie is transmitted, this problem will be more significant. Because received broadcast packets of wireless LAN (including IEEE802.11p) do not generate ACK packets, detecting collision of packets at the sender is difficult. Thus, we need a replica distribution scheme which is more robust to collisions. Network coding will be one of the useful strategies. Lee et al. propose random network coding-based information sharing scheme on V2V networks[6]. However they do not treat location dependent data. We are now designing a network coding based replica distribution scheme for location dependent data.

Very low vehicle density If the vehicle traffic is very low or the variation of vehicle density is large, distribution of intersection may fail due to the absence of receiver vehicles. One solution for this problem is to deploy fixed nodes to suitable locations. Because they do not move, strategies different from RD scheme are required for assigning distribution of replicas to fixed nodes. For minimizing the cost of the infrastructure, the number of fixed nodes should be small as long as sufficient query hit ratio is achieved and the layout of fixed nodes is important. We are now designing an enhanced version of RD scheme supporting fixed nodes.

Presentation of received data A requesting vehicle has to merge received reply messages and present them for the driver. Merging live pictures or movies taken by different vehicles at different timing and different angle will not be easy. If the pictures are taken only by a vehicle, the pictures will be merged by making a panoramic view[7]. However, if the pictures are taken by different vehicles, additional information and techniques will be required for eliminating the effect of the differences.

3.2. Issues of realizing Smart Blinkers

So far, various AR-based car navigation systems and driving assistance systems have been proposed[8][9][10]. The most important issue of such systems is how to visually identify vehicles. The body color, number plate and the shape of the body can be used for identifying a vehicle. However, in a real environment, there are many same colored and same shaped vehicles on roads. In nighttime, color and shape may not be useful. Comparing with color and shape, number plates are easier to treat because they are designed so that they can be easily identified anytime and anywhere. However, it will be difficult to take a picture of a number plate of a vehicle if the vehicle is not at front face of the requesting vehicle (a watching vehicle). Ukai et al. propose a scheme to identify a vehicle by detecting the lighting of a stop lamp and broadcast message from the braking vehicle[11]. This scheme does not need any additional equipments other than camera and V2V wireless communication devices. However, it is difficult to identify a vehicle when vehicles are moving on a signal-free road or a very congested multi-lane road where may vehicles stop and go at the same time.

Smart blinkers can be attached anywhere on a vehicle vody. They may be attached at the top of the body, side corners, and the center of the rear windshield. Multiple smart blinkers may be attached to a vehicle body. These multiple smart blinkers will be useful to identify the vehicle's position, shape, and dirrection correctly. If each blinker tells the information about the attached position to the watching vehicle, it will be used for improving the accuracy of the position estimation, estimating the shape and its moving direction.

Different from wireless LAN packets, messages sent from smart blinkers do not collide each other. Thus, they can be used for complementing wireless communication though the bit rate supported by smart blinkers will be very small compared to wireless LAN.

4. Conclusion

In this paper, we introduced two V2V communications systems which use visual information, Live Picture Car Navigation system and Navigation with Smart Blinkers. Visual information transmitted by wireless link may cause congestion and packet losses due to its large data size adding to the intermittent behavior of the link. On the other hand, visual communication using markers and camera does not cause congestion. Using both characteristics, we will be able to realize effective and useful communication services which support drivers.

References

[1] G. Tsuchida, T. Okino, M. Tamori, T. Watanabe, T. Mizuno, S. Ishihara, "Replica distribution of data associated with location on wireless ad hoc networks," Electronics and Communications in Japan, Part 1, Vol. 90, No. 10, pp. 67–80 (2007).

[2] G. Tsuchida, S. Ishihara, "Replica arrangement for location dependent data in consideration of network partition in ad hoc networks," International Journal of Communication Networks and Distributed Systems (IJCNDS), Vol. 2, No. 4, pp. 401–423 (2009).

[3] M. Yamanaka, G. Tsuchida, and S. Ishihara, "A replica distribution scheme for location-dependent information on vehicular ad hoc networks," in proc. of the 3rd International Workshop on Vehicular Ad Hoc Networks (VANET2006), pp. 98–99 (2006).

[4] M. Yamanaka, and S. Ishihara, "A scheme for distributing replicas of location dependent information requested by geocast on VANETs," IPSJ Journal, Vol. 50, No. 1, pp. 31–41 (2009). (in Japanese)

[5] Ronald T. Azuma, "A survey of augmented reality," Presence: Teleoperators and Virtual Environments, Vol. 6, No. 4, pp. 355–385 (1997).

[6] U. Lee, J-S. Park, J. Yeh, G. Pau, and M. Gerla, "Code torrent: content distribution using network coding in VANET," in proc. the 1st international workshop on Decentralized resource sharing in mobile computing and networking, pp. 1–5 (2006).

[7] K. Hirahara, C. Zhu and K. Ikeuchi, "Panoramic-View- and Epipolar-Plane-Image Understandings for Street-Parking Vehicle Detection," In proc of ITS symposium (2003).

[8] M. Katagiri, T. Sugimura, Y. Sakurai, T. Ikeda, "A Navigation System for Mobile Environment using Live Video. Mobile MagicView," IEIC Technical Report, Vol. 98, No. 490 (PRMU98 150-175), pp. 149–156 (1998). (in Japanese)

[9] K. Kojima, A. Sato, F. Taya, Y. Kameda, and Y. Ohta, "NaviView: Visual assistance by virtual mirrors at blind intersection," in proc. of 8th International IEEE Conference on Intelligent Transportation Systems (ITSC'05), pp. 627–632 (2005).

[10] S-J. Kim and A.K. Dey, "Simulated augmented reality windshield display as a cognitive mapping aid for elder driver navigation," in proc. of the 27th international conference on Human factors in computing systems (CHI'09), pp. 133–142 (2009).

[11] Y. Ukai, K. Uehara and M. Sato, "The determination of network address using image processing in vehicle to vehicle communication, " IPSJ SIG Technical Report, Vol. 2009-ITS-39, No. 5 (2009). (in Japanese)