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Vehicle to vehicle communication and platooning for SEV COMS By wireless sensor network

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Abstract: **With the aging driver increasing, the smarty automatic driving system needs to be proposed. We analyze the smarty automatic driving system to propose a smarty platooning control system based on the automatic driving system for elderly person. Firstly, the small automatic electric vehicle and the control devices are explained. Then we introduce the Wireless communication method in our system. Based on the communication between the vehicles, we design related control method and the path recognize method for platooning control system using in urban road. At last we do some experiments to verify the effectiveness of our system.**

Keywords: Platooning, Autonomous driving system, ZigBee, Digimesh, Vehicle to vehicle communication

1. INTRODUCTION

Nowadays the aging rate of the city of Kitakyushu is 25.5%. That is to say, there is one that 65 or older in four people. Especially, in Yahatahigashi Ku the percentage is up to 33%. Moreover, the special slope road, dense residential area and narrow roads make the public transportation unsuitable in this area. This situation makes eldly go out more inconvenient and harder.

In order to decrease the burden of eldly driver, prevent the traffic accident and realize the smoothly of traffic flow, our research combine the super small eclectic vehicle, the in-vehicle technology of ITS and so on to realize the traffic tools which can guarantee the safety of eldly driver and do some researches about platooning driving of automatic driving.

The existing researches about platooning driving focus on tracking the leading vehicle in highway environment. Our research is designed for platooning driving system utilizing communication between vehicles in urban road which has high transportation dense.

In this paper, we focused on the communication and platooning of the vehicles, including the inter-vehicle data collection and transmission, in order to find an effective way to support assist-help for old drivers for safety, reducing the rate of traffic accidents. We use two different kinds of wireless communication modules to make up the wireless transmission network. Throw this kind of communication network; the small electronic vehicles can transmission the needed message and the control signal to achieve platooning.

For the vehicles, the purpose is that by using the vehicle-to-vehicle communication technology and coordinating this network, we can use these kinds of system and car into the supporting help for the old driver in safety driving in the normal road.

This paper is mainly about using the data of its own and neighboring car's stat and the surrounding information, this vehicle can be drove into the platooning mode. So the distance between each car can reduce, in order to making the biggest using of the limited road space, increasing critical density of the happening of traffic jam and so on. And these multiple small electronic vehicles use these kinds of information to drive automatically when vehicles are driving in the platooning situation. Our research purpose is the development of communication and platooning system that suited the normal road.

Based on the automatic driving system(1) which is developed in the past we propose more efficient and safer platooning driving system by utilizing the wireless module to search the vehicle nearby for vehicle communication.

2. SUMMARY SYSTEM DESIGN

In this paper, we use ultra-small single-seat EV COMS shown in Fig.1. The sEV is made up of stereo camera, ultrasonic sensor, and GPS, IMU and control system. In this research, we use sensor-fusion technology to identify the obstacles. For short distance avoidance, we use the ultrasonic sensor with high sensitivity at a low price advantage. In terms of sensitivity, the ultrasonic sensor is less affected by the color and brightness, easy to transmission. In long distance obstacle detection, we developed an algorithm for obstacle recognition by utilizing parallax coming from stereo camera. GPS and IMU are used for recognizing the vehicle body angle and current position.

Fig.2 shows the structure of control system. From this figure we can see that the system is composed of the monitor PC, router, controller, the image processing PC and remote monitoring PC. The monitor PC is in charge of collecting IMU and GPS data, route generation and outputting the calculation result. The image processing PC is responsible for collecting camera data, obstacle recognition, white line recognition and outputting the calculation result. The remote monitoring PC takes charge of remote monitoring data and emergency handling. Controller is in charge of collecting all data, executing control model calculation and sending control values. Router takes charge of communication between monitor PC, the remote monitoring PC and controller.

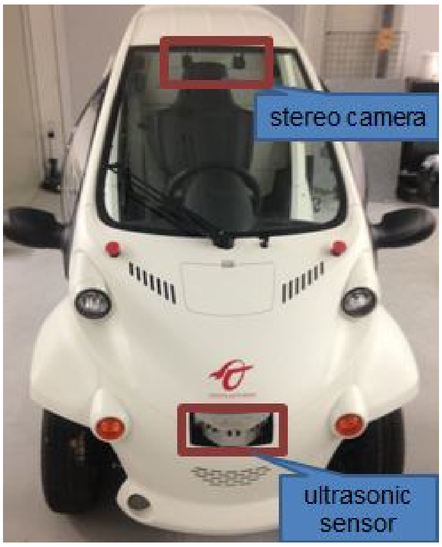


Fig.1 Ultra small EV COMS

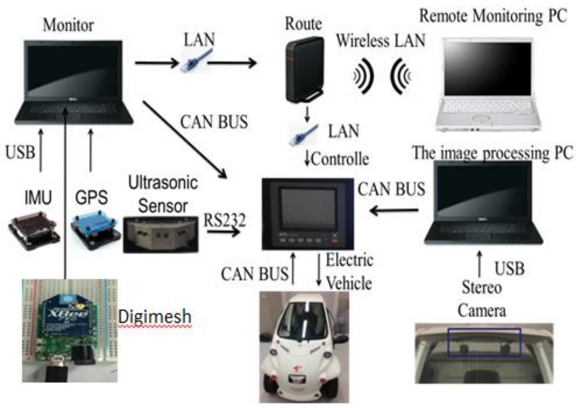


Fig.2. Structure of control system

3 INTRODUCTION OF COMMUNICATION SYSTEM

We designed a communication system which can transmit vehicle information to its and other vehicles' central controller by ZigBee module. And these multiple small electronic vehicles use these kinds of information to drive automatically when vehicles are driving in the platooning situation [3].

During the experiments which using the Zigbee module for communication, they had two problems. These problems have a big influence to this communication and platooning system. The first one is the connecting time to the communication network (Fig.3). And another one is the topology structure of the Zigbee module(Fig.4). In simple words, these must be a coordinator. This coordinator has to be carried in vehicle and connects all the surrounding vehicles. So the duties of this coordinator are: 1. set up communication network. 2. allow end device vehicle to join in the network. 3. throw this coordinator each node can communicate with others. From these above, we can see the coordinator is very important to my system. If the coordinator is disappeared, the all system will shut down.

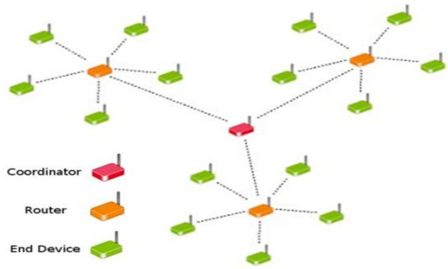


Fig.3. ZigBee network

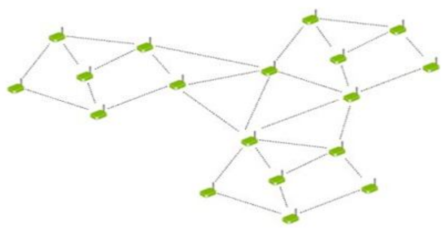


Fig.4. Digimesh network

We test two key parameters of ZigBee modules and Digimesh modules. The first one is end device need how long to get into the communication network. The second one is the received signal strength indicator (RSSI).

About test one by ZigBee; we use two Zigbee modules to test it. The first one acts as the coordinator and the second one act as the end device. We make these tests in the open field of our graduate school.

Zigbee module is controlled by AT command. So the network set up time and join time is decided by the time AT command needed (about 5 sec.)

Table 1 the relationship between distance and time to get into network by Digimesh

Distance	Time [two modules]	Time [three modules]
10m	<100 ms	<100 ms
20m	100 ms	100 ms
25m	180 ms	180 ms
30m	260 ms	268 ms
40m	500 ms	513 ms
50m	760 ms	780 ms
80m	1200 ms	1280 ms

By Digimesh, We use two modules to test it. Because of the Digimesh protocol, we don't need to set up the communication network. We just debug the Digimesh modules make them talk among them using p2p (equal to equal) datagrams. We change the id, channel and the distance address low into the same value. So these Digimesh modules can transmit data equally and don't need to act any role such as coordinator, rout and end device in order to set up communication network.

About test two by ZigBee, We test the RSSI of this Zigbee module. The data off RSSI determines communications quality among the Zigbee modules.

Table 2 the relationship between distance and RSSI of Zigbee

Distance	RSSI [with antenna]	RSSI [without antenna]
10m	-30 dbm	-49 dbm
20m	-30 dbm	-53 dbm
30m	-30 dbm	-57 dbm
40m	-30 dbm	-63 dbm
50m	-38 dbm	-66 dbm
60m	-49 dbm	-79 dbm
70m	-58 dbm	-81 dbm
80m	-60 dbm	NULL
90m	-66 dbm	NULL
100m	-70 dbm	NULL

From these data above, we can this Zigbee module has a good performance in the distance of 40 meter. And in the distance of 100m, it also has a good function of transmitting data.

In this research, the platooning distance of every vehicle is less than 30 meter. So this module can be used in the platooning mode. On the other side, the time need to join the network is not so good for the system.

By Digimesh, Just like Zigbee module, we test the relationship between the distance of two modules and the RSSI value. This time we use three different output powers.

Table 3 the relationship between distance and RSSI of Digimesh

	Low Power	Middle Power	High Power
10 m	-63 dbm	-54 dbm	-48 dbm
15 m	-63 dbm	-54 dbm	-48 dbm
20 m	-65 dbm	-57 dbm	-49 dbm
25 m	-69 dbm	-61 dbm	-51 dbm
30 m	-76 dbm	-64 dbm	-58 dbm
40 m	-81 dbm	-65 dbm	-61 dbm
50 m	NULL	-67 dbm	-64 dbm
80 m	NULL	-81 dbm	-75 dbm
100 m	NULL	NULL	NULL

From these data above, we can know that RSSI performance of both modules in the same situation of middle level output power. Their working distance is the same about 80 meters. Zigbee's RSSI is a little better than Digimesh.

Zigbee module is controlled by AT command. So the network set up time and join time is decided by the time AT command needed (about 5 sec.)

Digimesh module has a good performance in the distance of 20 meter. In the biggest working distance (80 meter) connecting time is less than 1.3 sec.

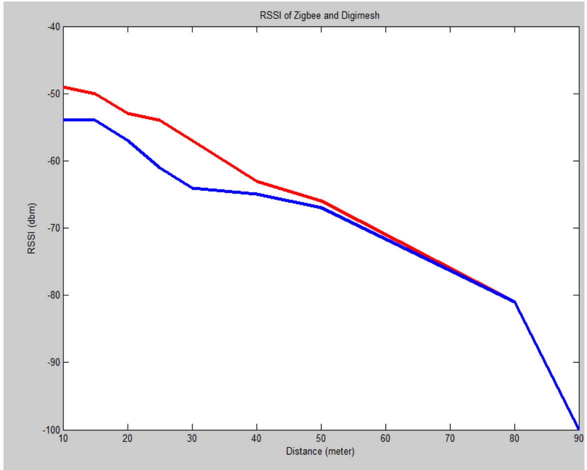


Fig.5. Performance comparison of Zigbee (red line) and Digimesh (blue line) about the received signal strength

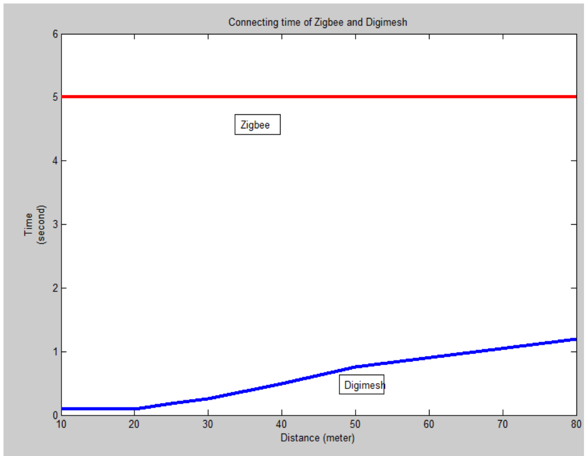


Fig.6. Performance comparison of Zigbee (red line) and Digimesh (blue line) about the connecting time

Table 4 Performance comparisons of Zigbee and Digimesh

	Zigbee	Digimesh
Network flexibility	Low ✕	Very high ○
Network sets up time	5 sec ✕	NULL ○
Network join in time	5 sec ✕	Less than 1.3 sec ○
RSSI (same output power)	Same △	Same △
Selection	✕	○

The comparisons result shows like Fig.5, Fig.6 and Tab 4 . So we use Digimesh to replace the Zigbee module. The benefits of Digimesh are less connecting time and talk among them using p2p (equal to equal) datagrams.

In this research, we use the CAN communication to get the status data of the COMS and sensors carried in the small electronic vehicle. For the vehicle to vehicle communication.

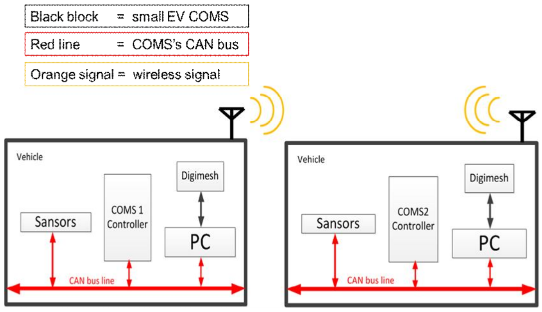


Fig.7 The specific image of communication system

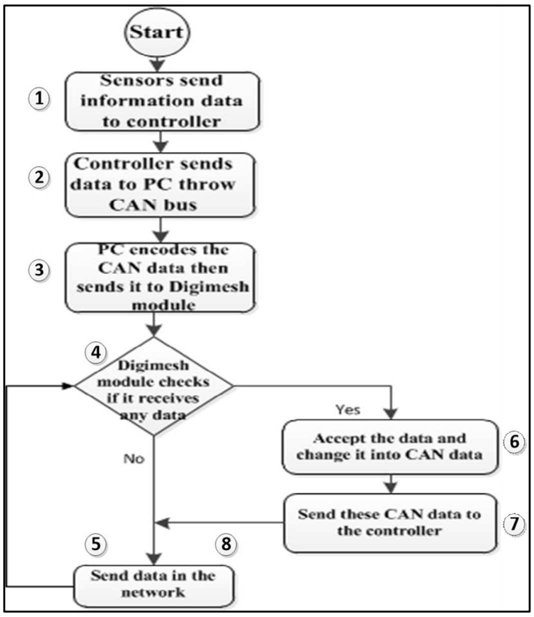


Fig.8 V2V Communication flow chart

Fig.7 shows the image of this whole vehicle to vehicle communication system and Fig.8 shows the flow of communication. Central controller collects the information come from the sensors used in the COMS. Then we use this information to achieve automatically driving. And vehicle sends collected information to other vehicles' controller by the Digimesh network. Throw these kinds of information, the following vehicles can not only automatically driving but also driving in the platooning mode. This system sets up two layers communication network to complete vehicle to vehicle communication.

1) First layer communication network which used inside vehicle is focused on collect varies of data which is sent by sensors used in the electronic vehicle COMS. Second layer uses Zigbee network to transmit information.

2) By using this two layers network, we can make a safe and reliable communication among multiple electronic vehicles.

4. PLATOONING DRIVING

In this research, the purpose of platooning system is to mainly analyze two movement situations when they driving in the platooning mode. One is normal type which is multiple vehicles driving in a strict line meanwhile they are in the automatic mode. This normal type is used in the situation of several vehicles start at the same start point and the destination point is also the same. For example, this type can be used in the community which has a lot of older people. When the older people want to go hospital, they can get together at first than they can go by using this platooning mode. I think it is safer and more effective. The other one is the join-in type. In the type, a new vehicle will join in the platooning in a crossroad. In this situation, the difference of normal type is the start points is not the same and vehicles will join in the same platooning at the crossroad.

When both vehicles get into the combine zone, according to the information of surrounding vehicles confirmation and the data exchanged with other vehicles throw the wireless network this new vehicle makes the judgment of when new vehicle joins in platooning and whether it becomes guiding car or not.

After decided the guiding car, both vehicles will control the car's movement and keep a certain and safe distance throw the sensors such as the stereo camera and ultra-sonic sensors to calculate the distance between two vehicles, the steering angles of the following vehicle which is for driving in a strict line and the emergency brake. When vehicles driving in the platooning mode, the communication network is divided into two parts the intranet and out net. The intranet is used to transmit the data among the controller, sensors carried in the COMS, steering motor, braking motor and the acceleration control unit. The out net is used to exchange data among the COMS. This exchanged data is used in controller for the platooning mode.

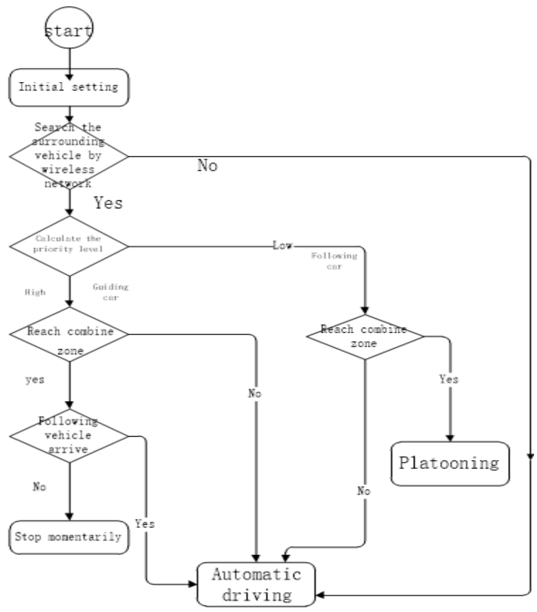


Fig.9 platooning flow chart

At first we input the data for the initial setting and start vehicle in the automatic driving mode. These data conclude the vehicle's speed, the position of combine zone, the distance between two vehicles and so on.

Then the small electric vehicle searches the surroundings to find if there have any wireless network existed and whether there have any vehicle near it or not. The vehicle will drive into the automatic driving mode when there is no wireless network or can't connect into network. If vehicle joins into the network and connects with other vehicles, these vehicles will exchange the driving information. And this driving information contains speed data, steering angle, position data and emergency braking data.

Then we use these transmitted information data to calculate the priority level of each vehicles. If this new waiting to join in the platooning vehicle has a low priority, this vehicle will wait the guiding car to get into the combine zone according to the position data. When the guiding car reached the combine zone, this new vehicle will start and use the stereo camera and ultra-sonic sensors to follow the guiding car and drive into the platooning mode. If guiding vehicles didn't get into the combine zone, this new vehicle just drives automatically and waits the guiding car to come. If new vehicle's priority is higher than guiding car, this vehicle will became the guiding car by comparing the calculation of each vehicle's priority. When new vehicle become the guiding car, it will first judge whether it reached the combine point. If new guiding car didn't get into the combine point, it will change into the automatic driving mode to drive. When this new guiding car reached the combine zone, it will make a decision about whether to stop momentarily. This decision is depended by the following vehicle. If the following vehicle arrives at the combine zone, these two vehicles will drive into the platooning mode. If the following vehicle didn't arrive at the combine zone, the guiding car will stop momentarily and wait for the following vehicle to arrive at combine zone.

5. EXPERIMENTS

We did the platooning experiment around the campus. In this experiment, we use sEV to test platooning driving system. At the beginning, we input a start point, end point position, vehicle speed and other parameters configured on the PC for remote monitoring, then sEV travels at 6Km/h from the starting point. The position model in EV driving unit continuous recognizes and calculates the current position to judge whether the vehicle has arrived at the target position. Once arrived, it will update the target position of the vehicle. In the whole process, we can us the remote monitoring computer to real-time monitor the status of sEV.

The first experiment is used for verified multiple vehicles' automatic driving and platooning by suing Digimesh module as shown in Fig.10. This experiment is mainly using the Digimesh module to exchange each other's information in order to achieve the platooning. The controller process this transmitted data by the algorithm that designed for automatic driving and platooning.

Fig.10 Platooning experiment 1

The result of this experiment shows that these cars can drive in the designed platooning mode and keep a safety distance between two cars. Throw the CAN communication and Digimesh communication, COMS is able to get the information of its status and transmit it to other COMS. The algorithm uses this kinds of data to make a smoothly platooning driving. Finally throw this experiment we can verified the effectiveness of this platooning mode.

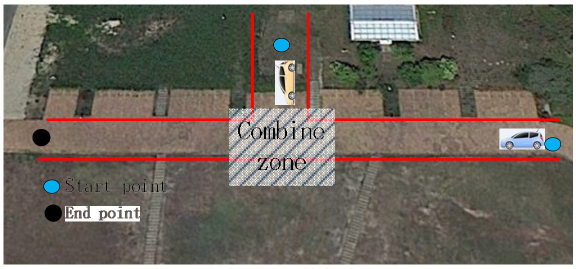


Fig.11 driving pathway

This second experiment is used to verified the algorithm for deciding which car is the leading car in the platooning when a new car waiting in the crossroad to join in the platooning. Just like Fig. 11 shows, these two cars transmit their own statue information before them start to move. According the algorithm I designed, the yellow car judge when to join the platooning and whether it takes the position of leading car by the data of blue's speed and position.

In this experiment, I set two situations. One, experiment 1, is that the blue care will not send the data to yellow one until the distance is very close which is not able for it to become the leading car. As shown in Tab.5. The other, experiment 2, is distance is still long enough for yellow to drive in the head. And I use the same speed of 6 km/h to make experiment. As shown in Tab.6.

Table 5 experiment image

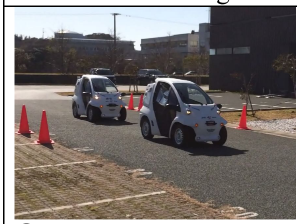
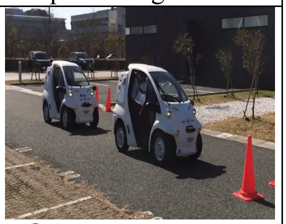
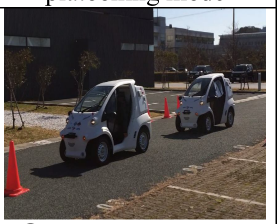
 ①cars start at their own start point	 ②two cars meet at the combine point
 ③two cars decide which one is the leading car	 ④ two cars start platooning mode
 ⑤ two cars keep a certain distance in platooning mode	 ⑥two cars reach their each other end point

Table 6 experiment image

 ①cars start at their own start point	 ②two cars meet at the combine point
 ③two cars decide which one is the guiding car	 ④two cars start platooning mode
 ⑤two cars keep a certain Distance in platooning mode	 ⑥two cars reach their each other end point

6. CONCLUSION AND FUTURE WORKS

In our research, based on the survey result and topographical features in Kitakyushu city, we designed and modified the small electric vehicle for elder and build automatic driving system. On the strength of that, we realized the platooning

We used Zigbee or Digimesh to exchange driving data between vehicles. The field experiments also verify the effectiveness of our system.

①V2V communication is working smoothly. These two vehicles can keep a safety distance to drive in platooning by using V2V communication.

②Vehicles can decide which one to be the guiding car by priority level.

③Vehicles can realize platooning of driving in a line and join in a platooning freely.

In the future, there are three aspects work need to be finished. First is research about automatic driving which are improving the absolute position correcting sensor for position recognition, the riding comfort for elder drivers and the stability of surrounding recognition at high speed. The second is the platooning research including supporting three vehicles and improving the communication stability. The last is the field experiment in simulated public roads like driving school will give a more real verification for our system.

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