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論 文
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A Design of a Simulation Apparatus for the Control of the Personal Rapid Transit(PRT) Vehicles

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Abstract – This paper presents a design of a simulation apparatus to evaluate an operational control algorithm for the PRT system. PRT systems require very short headways to increase the line capacity and a very reliable vehicle control algorithm for avoidance of the impact between vehicles. Therefore, it can be said that the development of an reliable operational control algorithm for the PRT systems is much more important than that of the hardware configurations. In this paper an apparatus is proposed which is composed of virtual vehicles, a central control system, a man-machine interface and monitoring device, making it possible for the designed operational control algorithm to be implemented and tested. For the test of the proposed apparatus a test operational control algorithm is designed and the experimental results show the effectiveness of the proposed simulation apparatus for test and evaluation of the PRT operational control algorithms.

Key Words : Personal Rapid Transit System, Operational Control Algorithm, Evaluation, simuation apparatus.

1. Introduction

The fundamental concept of the PRT system is to make it possible for the vehicle to go to its final destination without stopping and with very short headways, the vehicle control scheme plays a very important role in avoiding collisions between vehicles. The vehicle control module is basically made of three elements: the state information of the vehicles in front and in rear, vehicle dynamics, and the speed profiles or brake curves to control the vehicle speed. The speed profile is produced by the central control computer or by the vehicle on-board computer based on the state information of the vehicles in front and in rear [1][2][3]. In order to develop the vehicle control algorithm that determines the system performance, it is necessary to use an effective simulator and an evaluation tool to test the designed controller [4][5].

PRT systems are being developed in many countries. The first system implemented in the real world is the West Virginia University PRT systems that connects the city's downtown and the university campus since the early 1970's. It is still in operation today without any troubles related to system safety. Since the early 1908's european countries and U.S. have been trying to commercialize PRT systems. The representative research groups are Cabintaxi of Germany, Ultra of the UK, and Skyweb Express in the U.S. Recently Techvilla Ltd. in Finland, MicroRail PRT in U.S., Monic*PRT* in Singapore, and Skycab in Sweden have begun developing PRT systems[6].

In this paper the author propose an apparatus for the development of the vehicle control scheme for PRT, employing VME Bus type PowerPC process module and a monitoring device.

First the quadratic equation to produce the speed pattern for the vehicle is presented. Next the author shows the test operational scenarios which is for the normal mode and for the emergency mode. Finally the configuration of the proposed apparatus is shown and the effectiveness of the proposed apparatus is verified by the calculation results for the speed pattern of the vehicles which run with test operational scenarios for testing.

2. Speed patterns

When a vehicle is controlled by a fully automated system like PRT vehicle the speed control equipment is one of the most important part in the overall PRT control system. In order to achieve the collision avoidance performance each vehicle should follow its speed pattern produced by the central control system or by the vehicle on-board computer system. Fig. 1 considers the relative

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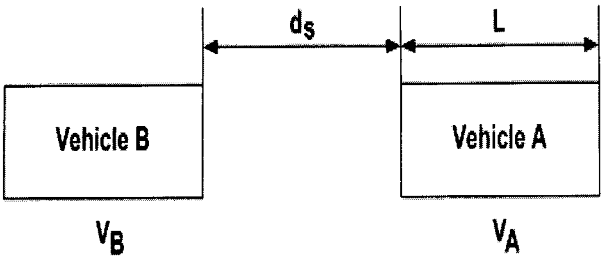

Fig. 1 Relative speed between two vehicles

speed properties between two vehicles. As seen in the Fig. 1 if the vehicle A (the vehicle in front) reduces the vehicle speed, the vehicle B (the vehicle in rear) should also reduce the speed to keep the safety distance d_s. In this case the initial speed of the vehicle B should be reduced to the final speed of the vehicle B. It is possible to employ Eq. (1) to produce the speed pattern to reach the final speed of the vehicle B with a deceleration to maintain the safe distance.

$$v_{Bf} = \sqrt{2a(D_B - d_{Bp}) + v_{Bi}^2} \tag{1}$$

Equation (1) means that if the initial speed of the vehicle B, v_{Bi}, the instantaneous vehicle position d_{Bp}, the block distance or the brick wall safety distance D_B, and the acceleration or deceleration a, are known, it is possible to calculate the final speed of the vehicle B, v_{Bf}. Generally the vehicle speed is a function time, however Eq. (1) indicates the speed versus distance which represents the vehicle speed pattern or the vehicle brake curve.

Eq. (1) does not consider the brake reaction time of the vehicle B, which means the delay time to activate the brake system of the vehicle B from the moment that the vehicle A has activated its brake system. By inclusion of the delay time for the brake reaction t_{Br} the Eq. (1) is modified as

$$v_{Bf} = \sqrt{2a(D_B - d_{Bp} - v_B t_{Br}) + v_{Bi}^2} \tag{2}$$

In order to accurate analysis of the speed patterns it is necessary to include the mobile characteristics of the PRT vehicle in the eq. (2) such as the dynamic properties of the vehicle or the friction force between the guideway surface and the traction component (rubber tire or steel wheel etc.). However in this paper we do not consider the dynamic properties of the vehicle or the friction force because the scope of the paper is to design the fundamental simulation apparatus to evaluate designed operational control algorithm rather than to design a physical vehicle. The fundamental idea for the simulation apparatus to evaluate the designed operational control algorithm is not changed even if eq. (2) is modified to include the dynamic characteristics of the vehicle.

3. Virtual operational scenarios

In this section we introduce two virtual operational scenarios: one is for the normal mode and the other is for the emergency mode. In the normal mode shown in Table 1. fourteen speed transition are set for the overall three km guideway. Each step has the initial speed that the vehicle is supposed to be operated in the entrance of the step and final speed to be reached in that step before the vehicle gets into the next step. The distance in each step has been determined arbitrary. On the contrary Fig. 2 shows the virtual emergency mode that implements the collision avoidance algorithm between two vehicles. In Fig. 2 both vehicles assume that there is no activation of the emergence brake for either vehicle running on the guideway at a constant speed. However, once the vehicle in front activates the emergency brake, the vehicle in real should activate its emergency brake as soon as it recognizes the activation of the emergency brake of the vehicle in front. Then the vehicle in rear should stop while maintaining the safe distance.

Table 1 Speed limit in each steps

Speed Transition	Distance /step	Total distance	Initial speed	Final speed
1	100 m		0 kmh	40 kmh
2	160 m	260 m	40 kmh	40 kmh
3	140 m	400 m	40 kmh	30 kmh
4	360 m	760 m	30 kmh	30 kmh
5	240 m	1000 m	30 kmh	60 kmh
6	500 m	1500 m	60 kmh	60 kmh
7	100 m	1600 m	60 kmh	40 kmh
8	160 m	1760 m	40 kmh	40 kmh
9	140 m	1900 m	40 kmh	30 kmh
10	360 m	2260 m	30 kmh	30 kmh
11	240 m	2500 m	30 kmh	60 kmh
12	200 m	2700 m	60 kmh	60 kmh
13	200 m	2900 m	60 kmh	30 kmh
14	100 m	3000 m	30 kmh	0 kmh

4. Simulation Apparatus

In this section an simulation apparatus that makes it possible to test and evaluate the designed virtual

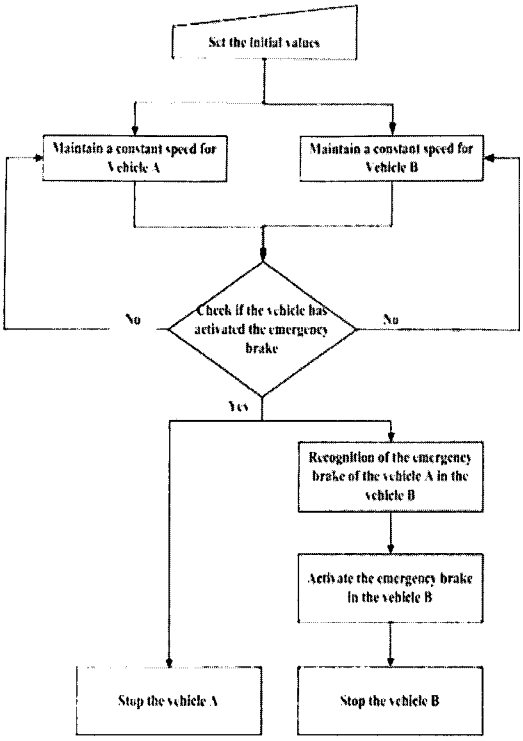

Fig. 2 Task flow for the emergency mode

operational algorithm is presented. The configuration of the simulation apparatus is composed of the central control module, the virtual vehicle module, and graphical user interface. The central control module collects the information from the virtual vehicle module that includes the vehicle operational status and speed for the four different virtual vehicles. It sends the parameter information to each vehicle for the calculation of the speed pattern in the virtual vehicle module. We employ a MPC7410 microprocessor-based VME bus processor module of Motorola Inc.. The Ethernet ports are used to transfer the vehicle status and the control information between the central control module and the virtual vehicle module by way of the TCP/IP (Transmission Control Protocol/Internet protocol) communication protocol. Fig. 3 and Fig. 4 show the conceptual configurations and the real hardware configurations of the simulation apparatus. As seen in Fig. 4 the power of the two microprocessors (MVME 5100) are provided by the VMEbus rack. A laptop computer that shows graphical user interface(GUI) is connected to the MVME 5100 microprocessors by way of Ethernet Lan hub. Fig. 5 is the overall simulation apparatus. Fig. 6 represents the graphic user interface. This figures shows the four vehicles that are operated on the guideway based on the normal mode operational scenario. The vehicle status and the control information are transferred between the central control module, virtual vehicle module and GUI. In the lower side of the figure there are information boxes indicating the vehicle status and the control information for each vehicle. The information for the vehicle operational status is shown in the left-hand side of the figure.

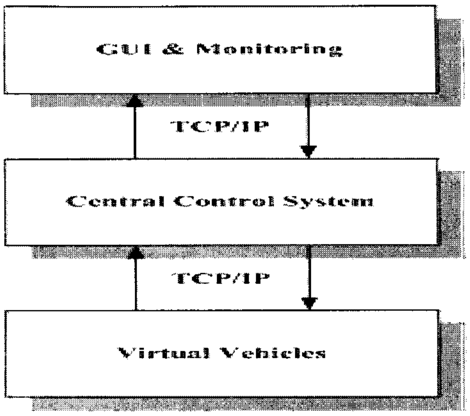

Fig. 3 Conceptual configurations

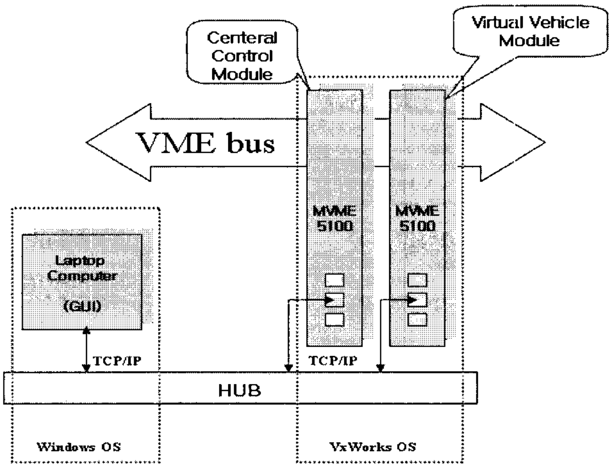

Fig. 4 Hardware configuration

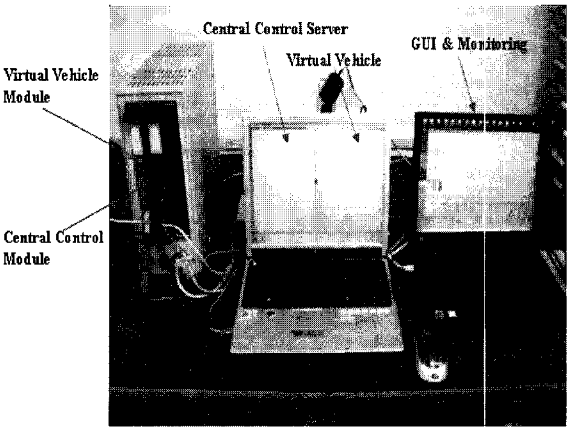

Fig. 5 Overall simulation apparatus

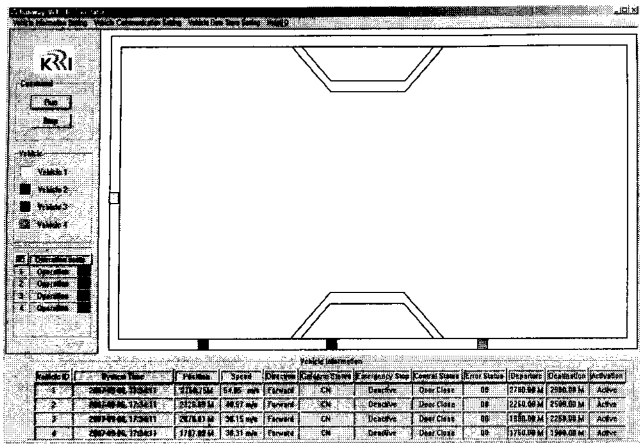

Fig. 6 Graphic user interface

5. Simulation results

The simulation results of the MPC7410 microprocessor for the normal mode and for the emergency mode are shown in Fig. 8 - Fig. 9. In Fig. 7, fourteen speed transitions are presented which are predetermined as the test operational scenarios for the normal mode (see Table 1.). In the figure the vehicle in front (dashed line) departed 200m earlier than that of the vehicle in rear (solid line). Each vehicle tracks the predetermined speed transitions very well, which means that the proposed simulation apparatus can be used as an effective evaluation tool of the vehicle operational algorithm. Fig. 8 and Fig. 9 show the simulation results for avoiding the impact between vehicles when the vehicle in front activates the emergency brake. In both figures the vehicle in front (dashed line) activates the emergency brake 1500m from the origin (dashed vertical line) and will be stopped. On the contrary the vehicles in rear (solid line) recognize the activation of the emergency brake of the vehicle in front with some delay but no matter where they recognize the activation of the emergency brake of the vehicle in front they follow the speed patterns to be stopped while maintaining the safe distance.

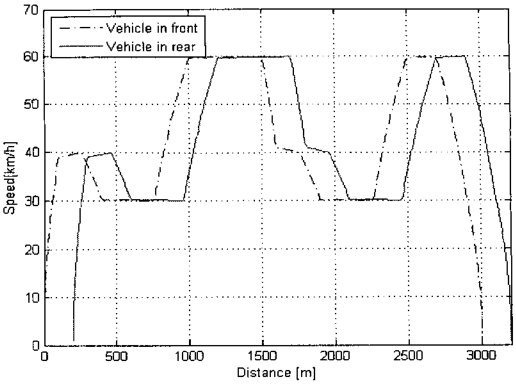

Fig. 7 Calculation results for the normal mode

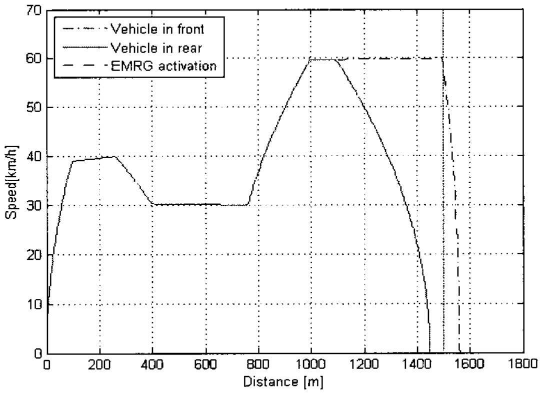

Fig. 8 Calculation results for the emergency mode (1)

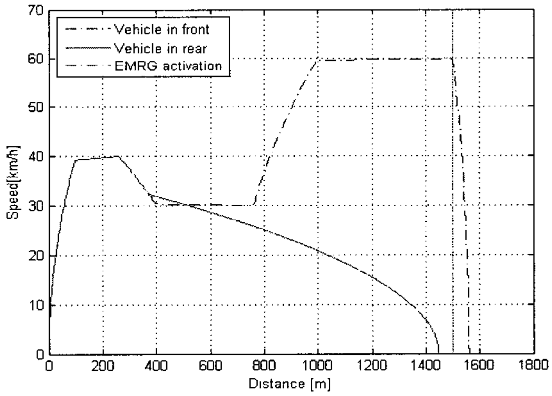

Fig. 9 Calculation results for the emergency mode (2)

6. Conclusions

First, in this paper we have introduced a test algorithm to control a vehicle on a guideway of 3 km in length. The test algorithm is composed of the normal mode that has fourteen speed transitions and the emergency mode to test the impact avoidance algorithm between vehicles. Speed patterns for the speed transitions were provided by the virtual vehicle module that receives the vehicle control information from the central control module.

Second, we have shown a hardware configuration for the assessment of the designed operational control algorithm. The processor that has been employed by the central control module and the virtual vehicle module is a commercial off-the-shelf processor. This has the advantage that the processor used for testing can be the same processor that is applied to the real system to control the real vehicle, with minor changes for the implementation of the control algorithm.

Finally, the operational control algorithms for PRT that have been reported up to now were focused on the computer simulation of vehicles, of system operations, and of line management in the overall control hierarchy point of view. However this paper proposes an apparatus which makes it possible to directly evaluate the characteristics of the vehicle operations on the guideway using real hardware. Further, this real hardware can use the same processor and operational control algorithms being designed for a real system. In this sense the apparatus proposed in this paper can reduce the time for the development, implementation and evaluation of the operational control algorithm for PRT.

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He was born in Seoul, Korea on July 3, 1964. He received the B.E. degree, M.E. degree from KwangWoon University, Seoul, Korea, and doctoral degree in electrical engineering from Kanazawa National University, Kanazawa, Japan, in 1987, 1989 and 1998, respectively. He worked at the Department of Mechanical and Aerospace Engineering, University of Virginia from 1998 to 2004 as a senior scientist and joined to KRRI(Korea Railroad Research Institute) from 2005. He is currently doing research for the development of the operational control scheme for PRT(Personal Rapid Transit).