

A Computer Simulator to Assess the Operational Scenarios for the Personal Rapid Transit Systems

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Abstract

The personal rapid transit (PRT) system is a small scale transportation system that employs a novel concept to solve the traffic congestion problem in the city area. The PRT system is a driverless on-demand system that a passenger calls a vehicle rather than waits for the vehicle. Therefore, one of the most important issues in the PRT system is how to control the vehicle with the satisfaction of the basic concept of the PRT system. In this paper a computer simulator is introduced to evaluate the vehicle operational control algorithm of the PRT system. The computer simulator has the commercial embedded processor boards that operate in the real time operating system and pre-designed vehicle control algorithm is coded into the processor boards. The experimental results present the effectiveness of the proposed evaluation apparatus.

Keywords : PRT (Personal Rapid Transit), Control system, Evaluation system, Speed profile

1. Introduction

For the past ten years, in the modern public transportation systems one of the most important issues is the development a novel technology to overcome the traffic congestions in the city area, and therefore get reduction of the emission rate that is able to contribute to solve the global warming problem [1].

The personal rapid transit (PRT) systems can be one of the solutions to overcome the above issue. The fundamental concept of the PRT systems is to make it possible for the unattended vehicle to go to its final destination without stopping and with very short headways. The vehicles are operated along the guideways and propelled by the electrical motors that are linear or rotational [2,3]. Since PRT system does not use the conventional rail system to transmit control signal information between wayside facilities and the on-board vehicle computer a specific communication system like wireless communication which is very popular technology during the last ten years may be able to be employed for the control of PRT vehicles, if the

reliability of the wireless communication is guaranteed [4].

In this paper the author presents a design of the computer simulator that makes it possible to test and assess the unattended vehicle operational control algorithm. The simulator consists of the central control module, the virtual vehicle module, and the graphical user interface. The central control module and the virtual vehicle module are operated by the VME Bus type PowerPC processor which is the commercial processor provided by Motorola Ltd. The operating system for the VME Bus type PowerPC processor is the VxWorks real time operating system. The graphical user interface is realized by the Intel Pentium II processor that runs on the windows operating system.

The vehicle operational control algorithm that is coded into the simulator processor 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. In order to develop the vehicle control algorithm that determines the PRT system performance, it is necessary to use an effective simulator and an evaluation tool to test the designed controller. First the author shows the simple virtual operational control algorithms that are composed of the normal operational

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Table 1. Speed Transitions

Speed transition	Distance /step	Total distance	Initial speed	Final speed
1	100 m		0 kmh	40 kmh
2	150 m	250 m	40 kmh	40 kmh
3	150 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

mode and the emergency mode. Second the quadratic equation to express the vehicle speed patterns is presented, then the configuration of the proposed computer simulator is introduced. Finally the experimental results show the effectiveness of the proposed simulator for the assessment of the pre-designed the vehicle operational control algorithm.

2. Virtual Operational Control Algorithms

The virtual operational control algorithms are composed of two scenarios that are for the normal mode and for the emergency mode. In the normal mode shown in Table 1 fourteen virtual speed transitions are set for the 3 km guideway. The final speed limits in each step are set arbitrarily.

For an emergency mode shown in Fig. 1 both vehicles assume that there is no activation of the emergency 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 rear 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.

3. Quadratic Equation for 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 sys-

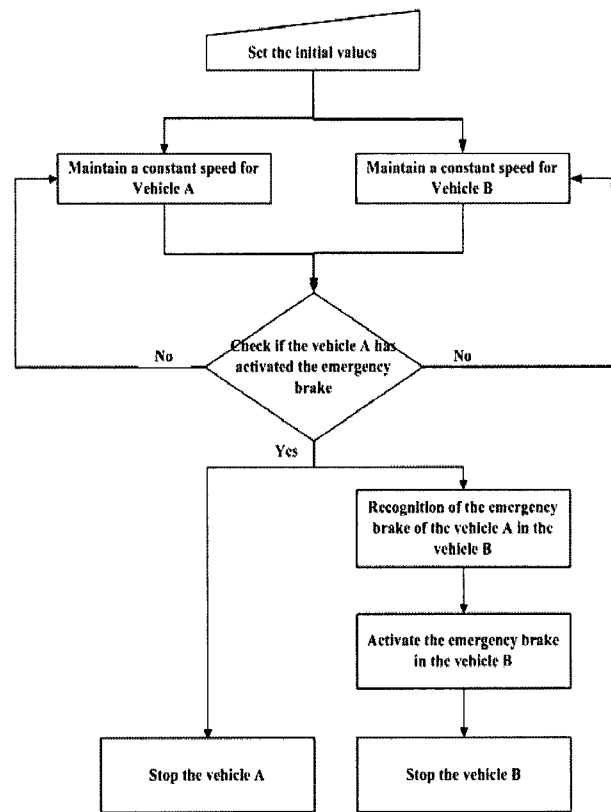


Fig. 1. Emergency Stop Mode

→ Deceleration or Acceleration a

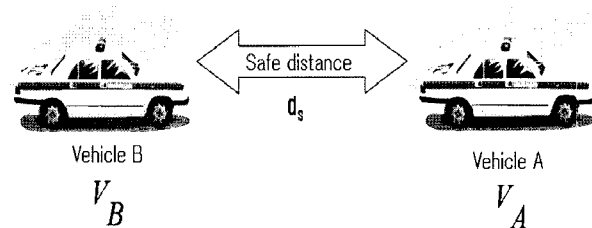


Fig. 2. Relative Speed Between Two Vehicles

tem. 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. 2 considers the relative 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 [5,6].

$$v_B = \sqrt{2a(D_b - d_{bp}) + v_{Bf}^2} \quad (1)$$

Equation (1) means that if the final speed to be reached v_{Bf} , the instantaneous vehicle position d_{bp} , the block distance or the brick wall safety distance D_b , and the deceleration a , are known, it is possible to calculate the speed of the vehicle B. Generally the vehicle speed is a function of 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

$$v_B = \sqrt{2a(D_b - d_{bp} - v_B t_{Br}) + v_{Bf}^2} \quad (2)$$

4. Configuration of the Computer Simulator

In this section the configuration of the computer simulator that makes it possible to test and evaluate the designed virtual operational control algorithm is presented. The configuration of the simulator 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 test bed. 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 experimental setup. Fig. 6 represents the graphic user interface. This figure 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 informa-

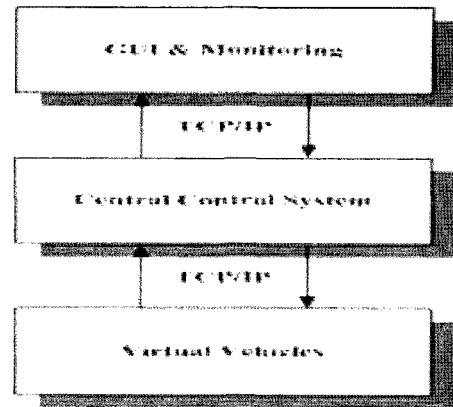


Fig. 3. Conceptual Configurations

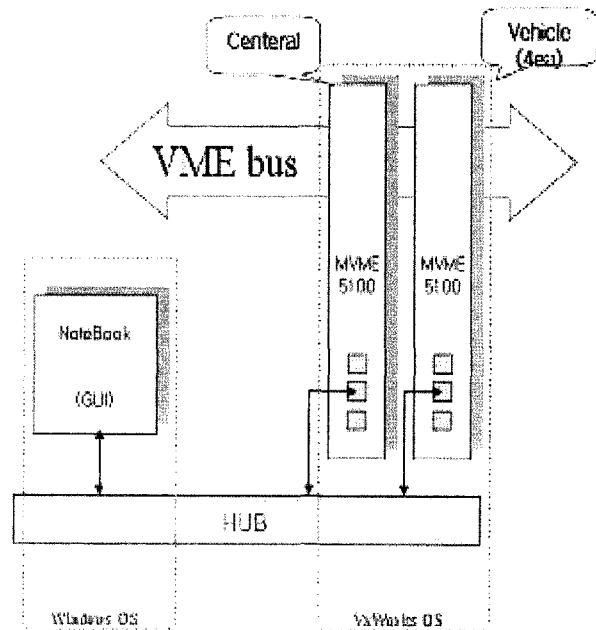


Fig. 4. Hardware Configurations

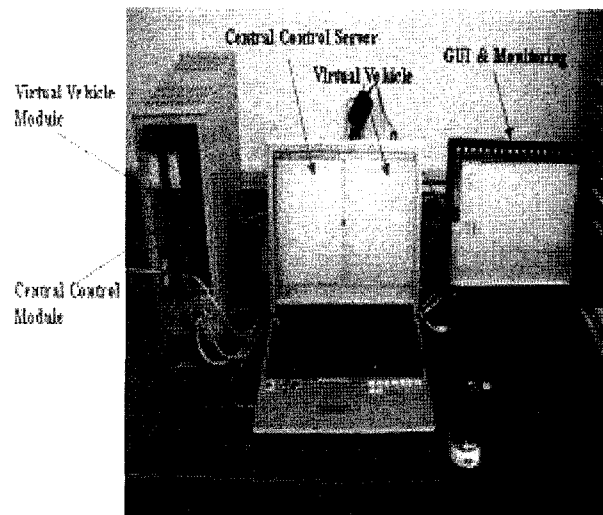


Fig. 5. Overall Experimental Setup

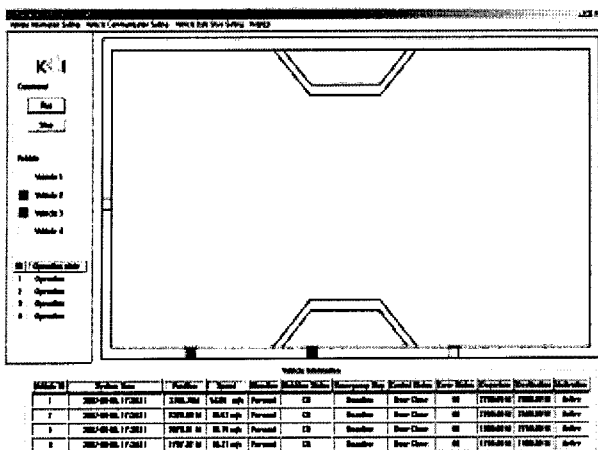


Fig. 6. Graphic User Interface

tion 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.

5. Experimental Results

The calculation results of the MPC7410 microprocessor for the normal mode and for the emergency mode are shown in Fig. 7~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 200 m earlier than that of the vehicle in rear (solid line). Each vehicle tracks the predetermined speed transitions very well, which means that the proposed computer simulator can be used as an effective evaluation tool of the virtual vehicle operational control algorithm. Fig. 8 and Fig. 9

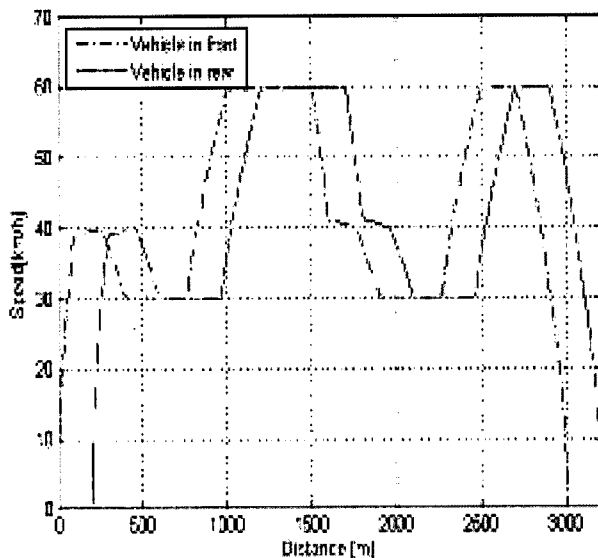


Fig. 7. Calculation Results for the Normal Mode

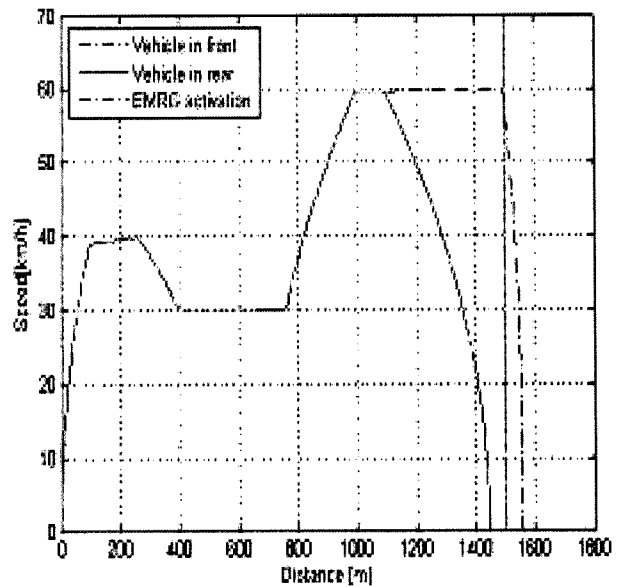


Fig. 8. Calculation Results for the Emergency Mode (1)

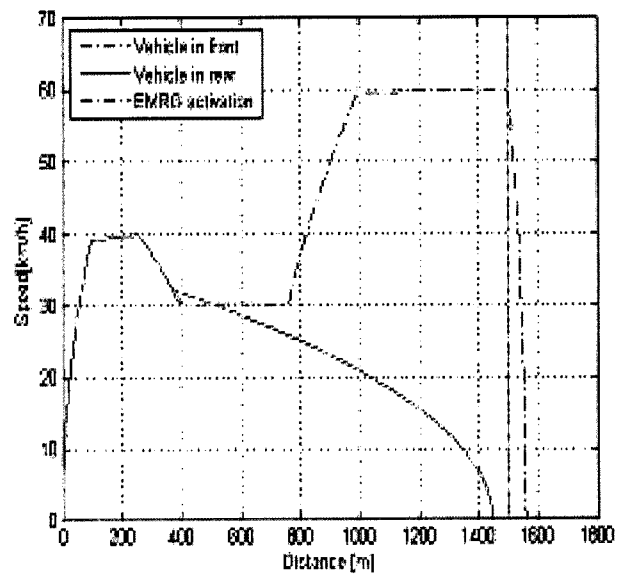


Fig. 9. Calculation Results for the Emergency Mode (2)

show the calculation 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 at 1500 m 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 pattern to be stopped while maintaining the safe distance.

6. Conclusions

First, in this paper we have introduced the virtual vehicle operational control algorithms to control a vehicle on a guideway of 3 km in length. The virtual algorithms are 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 based on the quadratic equation.

Second, we have shown the configuration of the computer simulator 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, 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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