PRT(Personal Rapid Transit) 시스템의 차량운행제어에 관한 검증 시스템 설계

A System Design for the Evaluation of the Operational Control Algorithm of Personal Rapid Transit System

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ABSTRACT

본 연구는 매우 짧은 차간 간격을 요구하면서 차량 간의 충돌을 피하기 위해서 매우 정확한 속도제어를 필요로 하는 개인 고속 이동 시스템의 운행제어 알고리즘의 검증을 위한 검증 시스템의 설계에 대해서 다룬다. 검증시스템은 모의 차량, 중앙제어 시스템, 모의지상설비, 모니터링 장치로 구성된다. 모의차량은 총 4EA의 서버(노트북)로 구성하며, 중앙(지역)제어시스템은 산업용 Motorola社의 PowerPC기반 프로세서 모듈 및 I/O 보드 장치로 구성한다. 모의지상설비는 National Instruments社의 PXI 산업용 제어기를 사용하여 구현한다. 설계된 검증시스템의 시험을 위해서 Labview Simulation Interface Toolkit 과 Matlab/Simulink 가 결합된 환경하에서 모의시험을 거친 시험용 알고리즘을 이용한다.

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1. Introduction

Congestion at road and air pollution problems in urban areas have encouraged to develop innovative travel modes. A innovative new transportation system providing many of the convenient features of private car, what is called personal rapid transit(PRT) system, offers a possibility to overcome the above mentioned problems.

The fundamental concept of personal rapid transit(PRT) is defined by The Advanced Transit Association as an automated guideway transit system in which all stations are on bypass, the vehicles are designed for a single individual or small group traveling together by choice on a network of guideways, and the trip is no-stop with no transfers. These innovative transportation systems are at the moment developed in many countries. West Virginia University has employed PRT system in the early 1970's to make the connection between the downtown and the university campus. This is the first system implemented in the real world and still in operation without any specific troubles that are related with the system safety. In other systems, Cabintaxi of Germany, Ultra of UK, Taxi 2000 of USA have been trying to commercialize the PRT system from the early 1980's. Recently Techvilla Ltd. in Finland, MicroRail PRT in U.S. Moni*PRT* in Singapore, Skycab in Sweden try to develop more feasible PRT system [1].

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In case of Korea since the PRT system has been introduced in the early 1990's a great effort has been invested for the development of the system and commercialization [2][3].
Since the fundamental concept of the PRT system is to make possible for the vehicle to go to its final destination without stopping with very short headway, in maximum speed 40-50[km/h], with 1-5 passengers per vehicle, the vehicle control algorithm plays a very important role to avoid the impact between the vehicles. The vehicle control module is basically made of the state information of the preceding and the rear vehicles, vehicle dynamics, and the speed profile that the rear vehicle should be tracked. The speed profile is produced by the central control computer or by the vehicle on-board computer based on the state information of the preceding and the rear vehicles[4][5][6][7]. In order to develop the vehicle control algorithm that manifests the performance it is necessary to use a effective simulation and an evaluation tool to test the designed controller. The authors have already published a paper that deals with a method to construct a control system using Labview Simulation Interface Toolkit and Matlab/Simulink combined system which is composed of modulized blocks. But the paper is confined to control system design only for the computer simulations.
In this paper we propose a novel method to construct an evaluation system for PRT vehicle control algorithm, using VME Bus type PowerPC process module, I/O board and monitoring device. The basic purpose of the evaluation system is to test if the simulated control algorithm is designed properly or not. For the test it is necessary to provide the virtual operational environment which is very similar to the real operational environment. The virtual operational environment will be discussed later.
First the paper presents the quadratic equation to produce the brake curve for the vehicle and then shows the vehicle control system for the simulation and proposes the evaluation system to test the simulated control algorithm. Finally we show the configuration of the virtual experimental set up to evaluate the simulated control algorithm.

2. Speed Pattern

In order to test the proposed evaluation system it is necessary to design a test control algorithm to be tested in the proposed evaluation system. The control algorithm for the test is based on the virtual scenario that two vehicles run in the main guideway at a constant distance with the same speed, then the emergency brake system of the preceding vehicle is activated and the brake system of the rear vehicle is activated and stopped before the preceding vehicle is stopped in order to avoid the collision between the vehicles.
It is necessary to consider the relation of the speed between the two vehicles to produce the brake curve or speed pattern of the vehicle as shown in Fig. 1. If vehicle A reduces the vehicle speed vehicle B should also reduce the speed with the safety distance d_s. In this case the initial speed of the vehicle B, v_{ci}, should be reduced to the final speed of the vehicle B, v_{cf}, with a deceleration, a, to maintain the safety distance. Thus if the deceleration is constant the speed of the vehicle B is

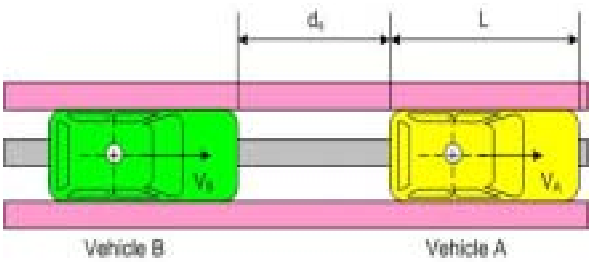

Fig 1. Distance between vehicles

$$v_B = \int_{t_0}^{t_f} -a dt = -at_f + at_0 = at_0 - v_{cf} \quad (1)$$

where t_0 is the initial time that the brake of the vehicle B is activated, t_f is the final time to be reached to the final speed. The integration of the velocity yields the moving distance of the vehicle from t_0 to t_f such as:

$$d_B = \int_{t_0}^{t_f} v_B dt = \int_{t_0}^{t_f} (at - v_{cf}) dt = \frac{1}{2} a\Delta t^2 - v_{cf}\Delta t \quad (2)$$

where $\Delta t = t_f - t_0$. If the distance D_b that the vehicle can move is limited by the rail block system like the conventional train system or by the brick wall speed control system which has a non-block system, we can know the distance D_b from the system specifications. Normally in the conventional rail train control system D_b is the one block distance and in the non-block system D_b is the distance which satisfies the brick wall condition. From this conditions the instantaneous position of the vehicle can be induced like this:

$$d_{Bp} = D_b - (\frac{1}{2} a\Delta t^2 - v_{cf}\Delta t) \quad (3)$$

From eq. (3) we can get the following equation which expresses the relation between the vehicle speed and the vehicle position:

$$D_b - d_{Bp} = \frac{1}{2} a\Delta t^2 - v_{cf}\Delta t = \frac{1}{2} a\left(\frac{v_B + v_{cf}}{a}\right)^2 - v_{cf}\left(\frac{v_B + v_{cf}}{a}\right) = \frac{v_B^2 - v_{cf}^2}{2a} \quad (4)$$

Eq. (4) yields

$$v_B = \sqrt{2a(D_b - d_{Bp}) + v_{cf}^2} \quad (5)$$

Equation (5) means that if there are the information for the final speed to be reached, the instantaneous vehicle position, the block distance or the brick wall safety distance, and the deceleration, then it is easy to calculate the vehicle speed. In reality the vehicle speed v_B is a function of time and the speed versus time indicates the vehicle speed pattern or the vehicle brake curve, corresponding to either the speed code received from the track signaling system or the speed command set by the driver during the operation like in the conventional ATC(Automatic Train Control) system.

In eq. (4) the term for the brake reaction time of the rear vehicle, which means the delay time to activate the brake system of the real vehicle from the moment that the preceding vehicle has activated its brake system, is not included. The inclusion of the delay time for the brake reaction yields

$$D_b - d_{Bp} = \frac{v_B^2 - v_{cf}^2}{2a} + v_B t_{br} \quad (6)$$

$$v_B = \sqrt{2a(D_b - d_{Bp} - v_B t_{br}) + v_{cf}^2} \quad (7)$$

where t_{br} is the delay time for the brake reaction of the real vehicle.

3. Control System for Simulation

We have already mentioned that a virtual test algorithm should be provided to test the proposed evaluation system. The test algorithm has simple scenario such as shown in flow diagram of Fig. 2. In Fig. 2 the initial values for the parameters should be set to calculate the speed patterns of the both vehicles. The both vehicles are assumed that if there is no any activation for the emergency brake the both vehicles run on the gudeway at a constant speed. However once the preceding vehicle activates the emergency brake the rear vehicle should activate its emergency brake as soon as it recognizes the activation of the emergency brake in the preceding vehicle. In order for the implementation of this simple scenario it is necessary to simulate the designed test algorithm for the debugging purpose. In this paper we employ a combined system which has Matlab/Simulink and Labview Simulation Interface Toolkit to simulate the algorithm that derives the speed patterns.

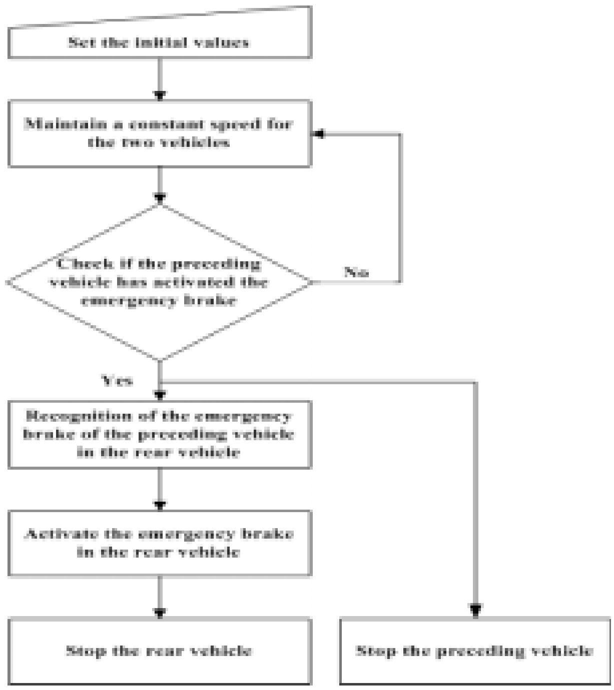

Fig 2. Task flow for the test algorithm

Fig. 3 shows the simulation model which runs on the Matlab/Simulink platform. In the figure the preceding vehicle speed pattern and the Rear vehicle speed pattern blocks calculate the speed pattern of each vehicle based on the parameter information transferred from the Initial set block. For the monitoring of the speed pattern we utilize Labview Simulation Interface Toolkit. Fig. 4 represents the front panel of Labview including the parameter initial values, speed pattern for normal state and speed pattern for emergency state.

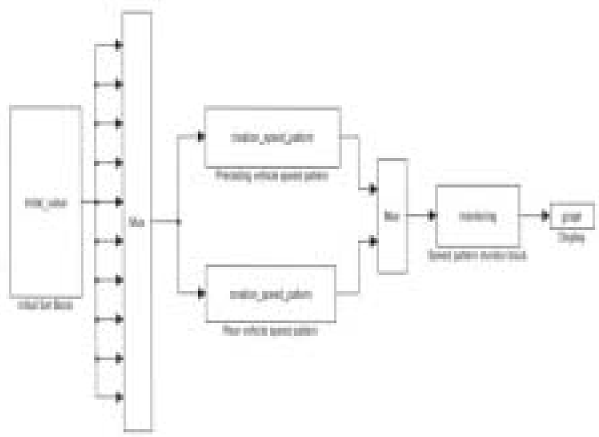

Fig 3. Simulation model

4. Simulations

For the simulations we set the initial parameter values as shown in Table 1. It should be noted that the vehicle control commands which means the deceleration of the preceding and rear vehicle in the emergency state are not the same. The reason is that it is necessary to stop the rear vehicle before the preceding vehicle stops in order to avoid the collision between the vehicles in the emergency state.

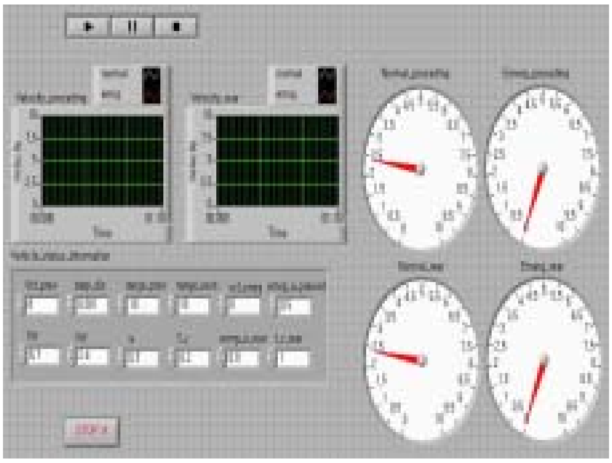

Fig 4. Labview front panel

Table 1. Initial parameters to calculate speed pattern

Variables	Value	Unit
Initial vehicle speed	6.7	[m/s]
Final vehicle speed in the normal state	2.4	[m/s]
Deceleration in the normal state	0.3	[m/s^2]
Brake activation delay time of the real vehicle	1	[sec]
Deceleration of the preceding vehicle in the emergency state	0.5	[m/s^2]
Deceleration of the rear vehicle in the emergency state	0.8	[m/s^2]
Final vehicle speed in the emergency state	0.0	[m/s]

However in the real vehicles since each vehicle has the same brake performance it is necessary to employ MBS(Moving Block System) control algorithm to avoid the collision between vehicles. In this paper we assume that the vehicle control command can be input by manual for the test of the evaluation system. Fig 5 and Fig. 6 show the simulation results. Fig. 5 is for the case of normal state. In this figure we see 1[sec] time delay in the rear vehicle to activate the brake, which means 6.7[m] in distance, due to the time duration to recognize the emergency brake activation in the preceding vehicle. But both vehicles reach the same final vehicle speed, 2.4[m]. with 1[sec] time difference. It is because the vehicle control command has set 0.3[m/s^2] in both vehicles. In Fig. 6 speed patterns for the emergency state are shown. The rear vehicle activates its brake with 1[sec] time delay in comparison with the activation of the preceding vehicle. However the rear vehicle stops with some safe distance before the preceding vehicle dose.

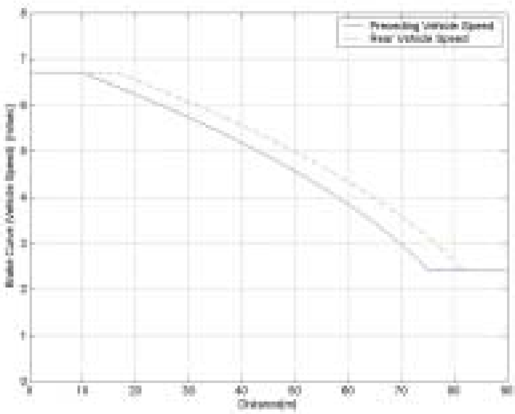

Fig 5. Brake curve for the normal state

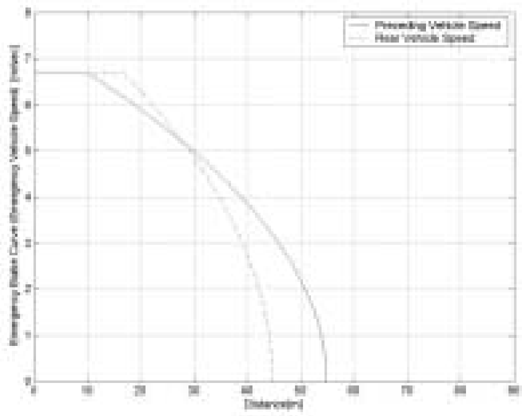

Fig 4. Brake curve for the emergency state

5. Evaluation System

In this section we deal with the configuration of the proposed evaluation system which is composed of virtual vehicle, central control system, virtual wayside facilities and monitoring device as shown in Fig. 7. The virtual vehicles can be implemented by using the several laptop computers which has the programed functions producing and displaying the vehicle status information. The number of the laptop

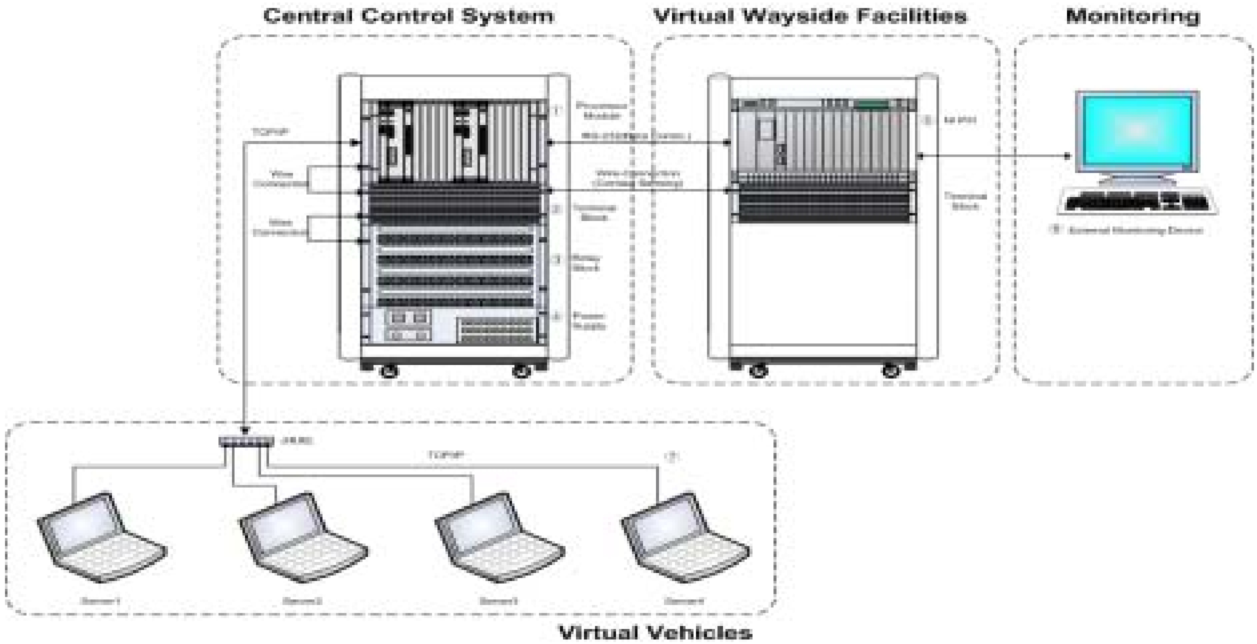

Fig 7. Simple configuration of the proposed evaluation system

computers can be arbitrary decided based on the system design. The central control system calculates the speed pattern of each vehicle using the information transferred from the virtual vehicles. In this paper we employ MPC7410 microprocessor based VME bus processor module of Motorola Inc. including RS-232 ports, ethernet ports and VMEVMI2536 I/O board. The ethernet ports are used to transfer the vehicle status information and the vehicle control information between the central control system and the virtual vehicles. The calculated results are transferred to the virtual wayside facilities that can be implemented using the PXI module of the National Instruments Corporation, by way of the RS-232 ports, I/O board and the relay block. The role of the virtual wayside facilities are to display the current status of each vehicle based on the information transferred from the central control system. The monitoring device is installed to check the status of the central control system, virtual wayside facilities and the virtual vehicles. It should be noted that we assumed there is no communication between the virtual vehicles to calculate the speed pattern using the on-board vehicle computer in the evaluation system. This is because we employed the centralized control method to control the vehicles, which means that the speed pattern for all vehicles are produced from the central control system.

6. Conclusions

In this paper we showed the quadratic equation to calculate the brake curve of the each vehicle and provided the simple operational scenario for the test algorithm which has been simulated in the combined environment of Matlab/Simulink with Labview Simulation Interface Toolkit. The simulation results showed the operational scenario worked very well in the virtual simulation environment. Finally we proposed the configuration of the evaluation system to test the simulated test algorithm, which is very plausible to the real operational environment.

In this paper we have not shown the test results of the proposed evaluation system. The next issue is to get the good experimental results produced from the proposed evaluation system.

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