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A Study on the Steering Control for the Next Generation of Guideway Bus Systems

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Abstract

Here, we mount the 4WS (Four Wheel Steering System) on a vehicle for the wheel centers of the vehicle to travel along the same trajectory. The steering control system consists of a feed-forward part and a feedback part. By applying a sliding mode controller, which is one of the non-linear control methods, and by correcting the steering angles, the high robustness is ensured. The control system uses a vehicle dynamics model of degrees of freedom to verify tracking performance of connected vehicles by conducting the numerical simulation.

Keywords: Vehicle Dynamics, Four Wheel Steering, Guideway Bus, Sliding Mode Control, Zero Off Tracking, Inverse Problem

1. Introduction

Measures through the provision of transport facilities, such as the introduction of new transportation to alleviate the traffic congestion, are being discussed actively due to urban traffic getting more congested. However, careful research and reviews on the measures should be made on the effects and effectiveness, in accordance with the investment facilities, before introduction of the measures, since the supply of these new transportations takes huge amounts of investment. From this perspective, the orbit bus system, one of the new newly emerging transportation means, is a public transport with a transport capacity of the medium railway and public city buses. In addition, the system can operate in a possible road segment and has is superior compared to other modes of transport [1] [2] in terms of the costs, including construction costs and operating expenses. In this study, public transport, to which the automatic driving technique is applied, with small and medium transport capacity, is investigated. When the ranks of vehicles operate, in order for the tread centers of the front and rear wheels to travel in the same orbit, the 4WS (Four Wheel Steering System) is mounted on large connected buses. Here, using a vehicle dynamics model of the degree of freedom and numerical simulation, the results of the tracking performance for the target course are reported.

2. Automated guideway bus system

As shown in Figure 1, in the system, multiple large buses, mechanically connected using single draw bars, drive along the magnetic markers installed at equal intervals on the dedicated track. Vehicles run on a dedicated track in automatic operation, with the front and rear tread centers of the wheels following the same orbit, and each vehicle having an independent control system. To achieve an optimized road alignment, the 4WS (Four Wheel Steering System) is mounted on vehicles as a required function. The position information of vehicles is obtained and the steering is controlled based on magnetic markers embedded in the same interval on driving roads. Magnetic sensors for detecting magnetic markers and necessary instruments, including the gyro sensor to detect the vehicle states necessary for the steering control, are mounted on the vehicles [3].

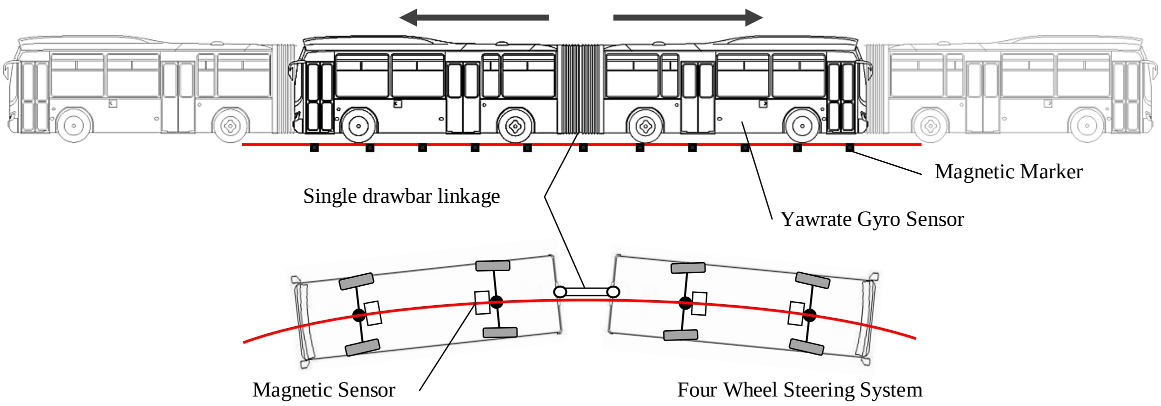

Fig. 1: Automated guideway bus system

3. Steering control system

3.1 Feed-forward control system

As shown in Figure 2, the steering patterns making commands in the feed-forward control system are determined by linear vehicle dynamics and characteristics of the target course. When the front and rear wheel tread centers travel to draw the same orbit, the attitude angles of the vehicle, with respect to any course positions, are determined uniformly, since the two dots in the front and the rear of the vehicle are restrained with respect to the target course. Therefore, when the vehicle passes the magnetic markers, the coordinates and the postures of it are functionalized and entered into the control system database. Using this data, based on sequentially updated speed information and location information of the vehicle, the time changes of the vehicle state quantity are calculated. Using the vehicle state quantity, the steering angles of the front wheels and the rear wheels are calculated by reversely calculating the equation of the plane of the vehicle dynamics model with two degrees of freedom station.

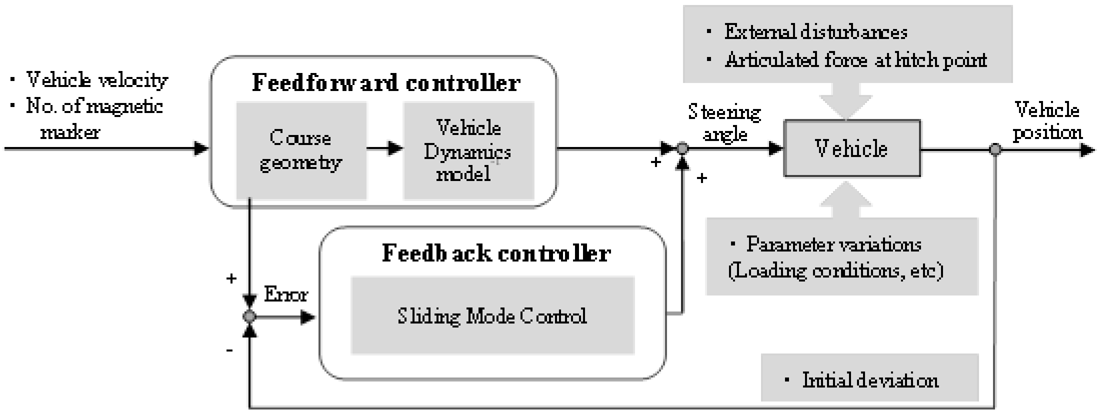

Fig. 2: Steering control system

3.2 Feed-back control system

Horizontal deviation occurs due to the changes in the characteristics of the vehicle not considered in the feed-forward and an external force, due to the mechanical connection between the vehicles. Modified assist steering angles given feedback after detecting a deviation, caused by such a disturbance, are added to the steering angle of the feed-forward. Since there are many uncertain factors in specifications of large vehicles, and large vehicles have uncertain factors and unknown parameters, such as the load fluctuation and characteristic changes of tires according to the number of passengers, control systems require a high robustness. Here, a sliding mode control was applied using robust control, which is relatively easily introduced. When passing through the magnetic markers, the center position of the vehicle at the position of front and rear wheels, and the width of the target course deviation information are obtained. The horizontal deviation between the magnetic markers is estimated based on dead reckoning, using a vehicle state amount. As a vehicle state amount, the horizontal slip angles of the vehicle body, which are difficult to measure, are estimated using a state observer.

4. Simulation

The simulation system used in this simulation is shown in Figure 3. The dynamics model of large vehicle motion simulation software, TruckSim, was used as the vehicle dynamics model. By calculating steering angles from the steering control system for vehicles configured to Simulink, each vehicle model is provided. The connection of the two vehicles was to reproduce the mechanical connection using the single draw bars. Coordinates of the connection point are calculated by calculating the vehicle dynamics model. Using the coordinates, the connection forces of stiffness and damping are calculated, and are substituted by an external force for each vehicle model. At the point of connection, the transfer of the moment is not carried out, and the power is transferred in the horizontal direction.

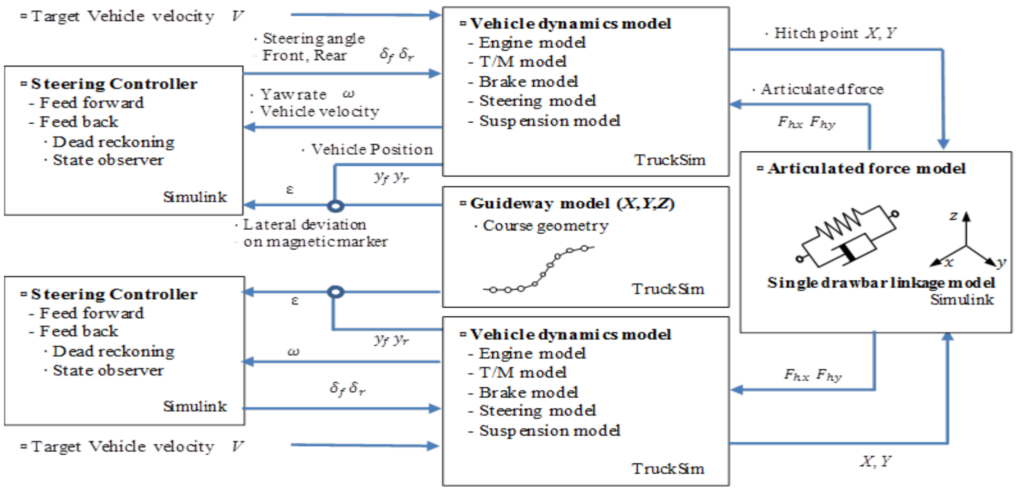

Fig. 3: Simulation system

The dimensions of the vehicle are shown in Table 1. A single lane change is set as driving conditions as shown in Figure 4. Functionalization was done in the feed-forward in advance in order to calculate the steering angles. Lane Change distance L was simulated from 60 m to 100 m. The running speed of the vehicle is constant at 40 km/h, and magnetic markers on the course were set up at 2 m intervals. Detecting degree of horizontal deviation of the magnetic sensor is set to have a ±10m in error with respect to the target course to achieve a probability of regular distributions.

Table1: Vehicle specifications

Parameter	Value	Units	Parameter	Value	Units
Vehicle length	6.99	*m*	Cornering stiffness	199630	*N/rad*
Front axle to vehicle c.g.	2.05	*m*		248193	*N/rad*
Rear axle to vehicle c.g.	1.66	*m*	Vehicle mass	8300	*Kg*
Front hitch point	3.875	*m*	Length of drawbar	1.4	*m*
Rear hitch point	3.115	*m*	Yaw moment of inertia	28225	$Kg\cdot m^2$

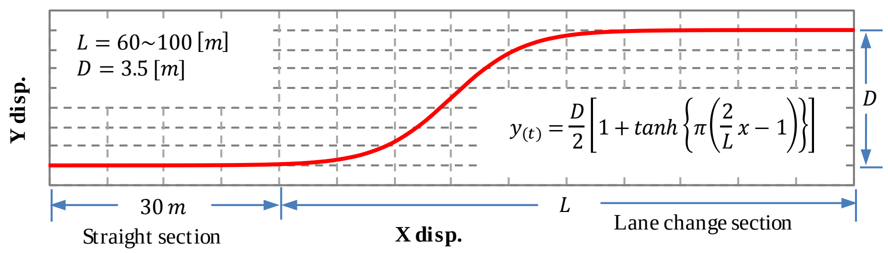

Fig. 4: Target Course

5. Result and discussion (tracking performance of the connection vehicle)

As the vehicles are connected mechanically in the present system, connecting force arises at connected points, and acts as a disturbance for the movement of the vehicle. Due to strict safety standards for the ranks of the autonomous vehicle operations, the early introduction of the system into actual traffic at home and abroad is not easy. Thus, according to a suggestion that the driving force of the rear vehicle should be made void like trailers, only the preceding vehicle is made to have driving force to pull the rear vehicle, which has no driving force. In this review, since the vehicle drives at a constant speed, the speed of the subsequent vehicle is supported by the driving force of the preceding vehicle, the subsequent vehicle being pulled by connecting devices. Furthermore, the preceding vehicle and the follow-up vehicle are equipped with all-wheel steering control system. Figure 5 indicates the relationship between street and lane changes and the integral of the second side deviation error (ISE). As can be seen from the results, it was found that almost the same follow-up performance as a single vehicle's was shown. Despite the connection force interference, the variation is suppressed by modifying the steering, and the high robustness of the sliding mode was confirmed.

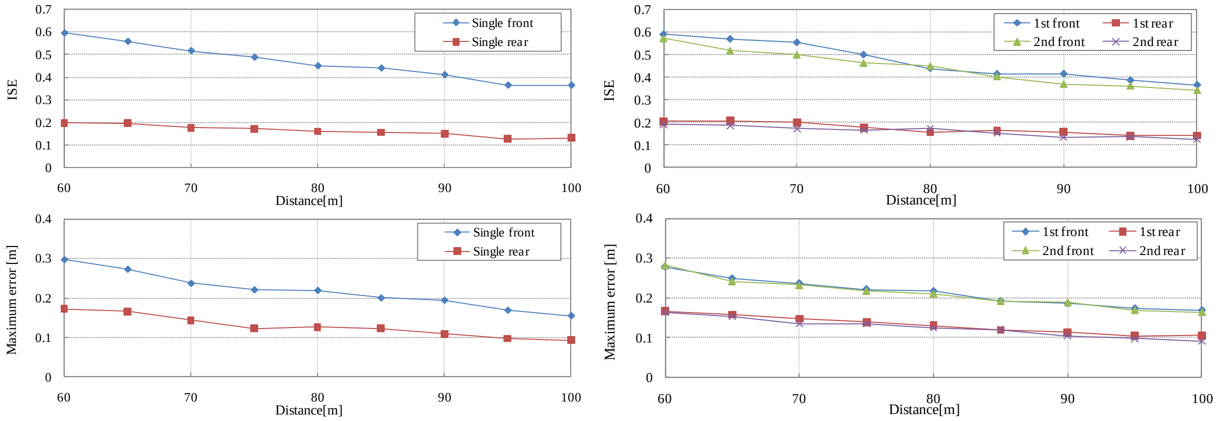

Fig. 5: Influence of lane change distance

6. Conclusion

The steering control system with the sliding mode was built on the target connected buses equipped with the all-wheel steering system. In addition, according to the results of a review of the numerical simulation using vehicle dynamics model of freedom, despite the connection force and interference in the machine connection, the same follow-up performance of a single vehicle with the support of high robust performance was confirmed.

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