Research and development of fully automated vehicles

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ABSTRACT

Automated truck platoon is focused on being able to improve the fuel economy and operation cost as next freight transportation system. In order to achieve 15 % of CO_2 reduction, an automated platoon system with closed gap distance of 4 m, have been developed. Trucks are equipped with automated steering and speed control system so that vehicles can travel at closed gap distance alone the lane. Automated platoon composed from three heavy duty trucks and one light duty truck has been demonstrated successfully at gap distance of 4 m.

1. Introduction

Automated vehicles being able to improve safety, fuel economy and traffic efficiency which are main issues on automobiles are anticipated as next generation automobiles. Currently, automated vehicles which must become next generation automobiles are being developed in Japan, Europe and United State America. Especially, automated truck platoon is focused on being able to improve the fuel economy and operation cost as next freight transportation system.

In 2008, a national project for reducing CO_2 gas emitted from heavy duty trucks on the highway, called "Energy ITS," was initiated in Japan under the auspices of the New Energy and Industrial Technology Development Organization. The mission of this project is to build an automated platoon system with closed gap distance which will be able to reduce CO_2 gas emission without engine modification. It has been already proven through many studies that the air-drag of each truck can be reduced by the closing of gap distance between trucks, resulting in improvement of fuel consumption. [1] In order to achieve 15 % of CO_2 reduction, an automated platoon system with closed gap distance of 4 m, have been developed and also the automated platoon within three heavy duty trucks have been tested at a speed of 80 km/h on oval test track.

In this paper, automated platoon technologies developed in this project will be described.

2. Concept of Automated Platoon

While it is required for platoon to keep the gap distance closely in order to improve fuel economy by reducing the air-drag, the task of keeping of closed gap distance on mixed traffic within conventional vehicles will be difficult for human drivers because of limited human's physiological response time. Automated vehicle control will be essential for keeping of closed gap distance. Both Lateral and longitudinal control can be made automatically trucks in platoon. Image of platoon is illustrated in Fig.1. The Steering is controlled automatically so that vehicles can keep the lane alone the painted lane line and also the propulsion of engine and the brake is controlled automatically for keeping gap distance between vehicles.

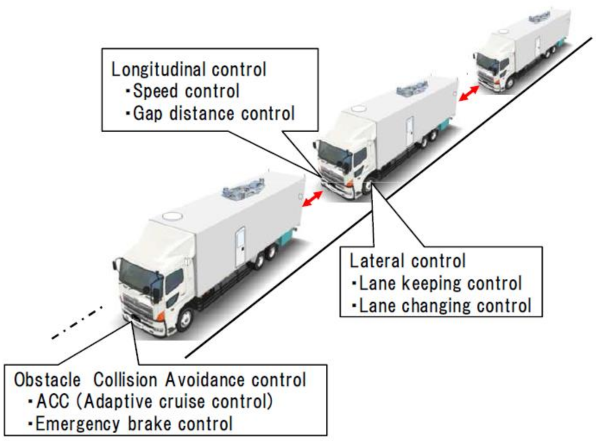

Fig.1 Concept of automated platoon

3. Detail of vehicle control

3.1 Lane keeping control

Block diagram of lane-keeping control system is shown in Figure 2. Nonlinear model based control algorithm was applied to the path following. [2]

The control algorithm consists of feed-back control and feed-forward control module in order to compensate the time lag of sensor and actuator. Feed-back control module can compensate the deviation of the lateral displacement and yaw angle and Feed-forward control module compensates the error due to both the cant and curvature of road.

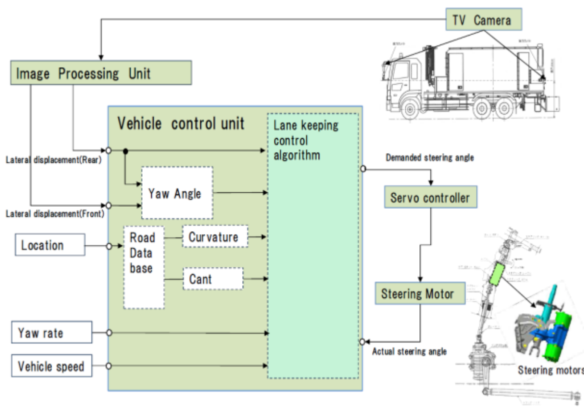

Fig2. Block diagram of lane keeping control system.

The lateral displacement and yaw angle with respect to white lane-marking line is measured by 2 kinds of lane detection sensor which are TV cameras and laser mounted on the left side of a truck. These sensors are mounted on so as to look down road surface in order to prevent the misdetection under the condition of rainy weather or against sun beam. The lateral displacement can be detected by the image processing unit which can recognize the while lane line from the image captured by TV cameras and laser. The yaw angle can be calculated from both lateral displacement of front and rear.

3.2 Longitudinal Control

For longitudinal control, in order to achieve precise controllability under the transient condition such acceleration and deceleration, cooperative distance control algorithm using the vehicle to vehicle (V-V) communication has been developed. The data concerning to vehicle speed, acceleration and deceleration rate of a leading truck is transmitted to following trucks by using V-V communication. Gap distance can be measured by 76GHz mill wave radar and laser radar. The engine propulsion and braking of a truck are controlled to maintain the inter-vehicle distance constantly.

4. Experimental vehicles

Experimental trucks have been developed in order to evaluate lateral and longitudinal controllability and fuel economy.

Figure 3 shows the configuration of experimental trucks. TV cameras and laser sensor are mounted on the top of the cabin and the rear of the cargo compartment on the left side. A mill-wave radar with 76GHz and a LIDAR for distance detection between vehicles are mounted near the front bumper. The steering motors for lane keeping are mounted on steering shaft. Radio-wave based inter-vehicle communication unit with 5.8 GHz and the communication protocol was developed specifically for platoon. HMI unit has been developed for the interface between human driver and automated control system.[3] Mission of human driver during automated control mode is to survey the control state by using display of HMI unit. If control system will be broken, human driver will take over the steering and braking operation.

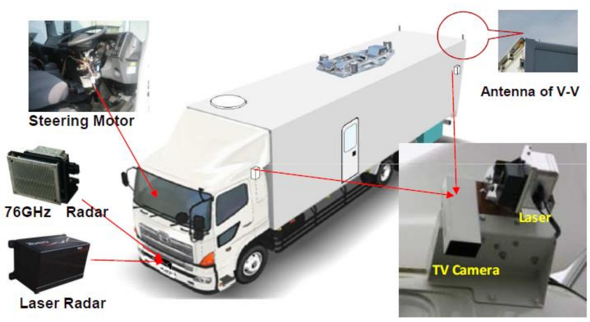

Fig.3 Experimental automated truck

5. Evaluation test result and demonstration

Controllability of lane keeping and gap distance has been evaluated on oval test track and new express-way under the construction. The lateral deviation on lane keeping control is approximately ±0.2 m during the curved road with 180 R. Longitudinal deviation for the Control of gap distance within platoon is approximately ±0.2 m at a constant vehicle speed of 80 km/h and ±1.0 m during the deceleration of 0.4 G.

It has been proven to achieve highly accurate controllability during emergency braking by using V-V communication.

Fuel economy of the platoon composed by tree heavy duty trucks has been evaluated on test track. The saving rate of fuel consumption due to gap distance is shown in Fig. 4. Fuel economy of platoon can be improved up to 15% at the condition of gap distance of 4.5 m compared to the single truck operation.

Finally, automated platoon composed by three heavy duty trucks and one light duty truck has been demonstrated successfully at gap distance of 4 m.

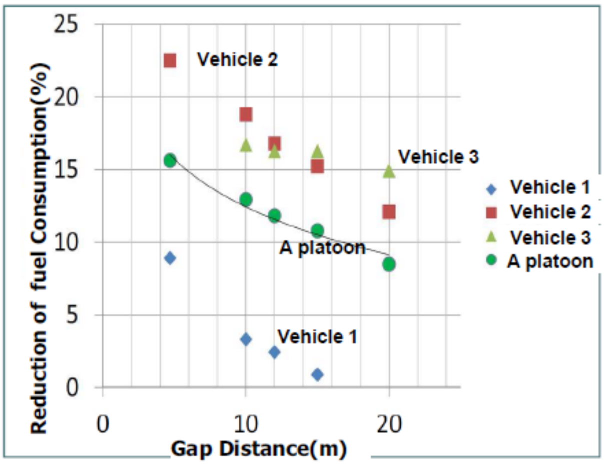

Fig.4 Result of fuel economy by platoon with 3 trucks

6. Conclusion

The automated platoon system with closed gap distance of 4 m, have been developed in order to improve fuel economy and safety on mixed highway traffic. Automated platoon composed from three heavy duty trucks and one light duty truck has been demonstrated successfully at gap distance of 4 m.

However, there are some non-technical issues to be solved so that automated platoon can be implemented to next freight transportation.

References

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[3] S.Kato, " Human Machine Interface of Platoon Systems " JSAE proceedings, No.7-10,2010, pp.23-28