Lateral Vehicle Control Based on Active Flight Control Technology

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In this paper, a lateral vehicle control using the concept of control configured vehicle (CCV) is presented. The control objectives for the lateral dynamics of a vehicle include the ability to follow a chosen variable without significant motion change in other specified variables. The analysis techniques for decoupling of the aircraft motions are utilized to develop vehicle lateral control with advanced mode. Vehicle lateral dynamic is determined to have the steering input and control torque input. The additional vehicle modes are also defined to using CCV concept. We use right eigenstructure assignment techniques and command generator tracker to design a control law for an lateral vehicle dynamics. The desired eigenvectors are chosen to achieve the desired decoupling (i.e., lateral direction speed and yaw rate). The command generator tracker is used to ensure steady-state tracking of the driver’s command. Finally, the developed design is utilized by using the lateral vehicle dynamic with four wheel.

Key Words: Active Control Technology (ACT), Control Configured Vehicle (CCV), Flight Control System, Lateral Vehicle Control, 4WS, Eigenstructure Assignment, Command Generator Tracker, Motion Decoupling, Multi-variable Control

1. Introduction

Advanced aircraft such as control configured vehicles (CCV) provides the capability to accomplish the desired flight movement. In order to develop advanced aircraft, active control technology is imported in the early state of flight design. Active control technology make a remarkable improvement in both flight capability and maneuverability by adding new loop to traditional SISO system, that is an extended MIMO system.

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The elevator, rudder, flapron and canard of advance aircraft assign the aircraft to a new degree of freedom (longitudinal mode and lateral mode) which is related to position maintenance and change under altitude and direction, and make a flight movement to the specific direction (Siouris et al., 1995; Sobel and Shapiro, 1985a; 1985b). Though these movement characteristics are above pilot’s ability, it can be realized in combination with computer control. Control technology also ensure the stability problem such as fault management.

Meanwhile, vehicle has the basic movement characteristics such as acceleration, deceleration, moving, lane change, rotation and stop by the handle, actuator, and brake of vehicle. Vehicle control efforts have been focused on improving the vehicle maneuverability and the straight line stability (Kachroo and Tomizuka, 1995; Matsumoto et al.,
In this paper, the CCV concept for vehicle was expanded from the previous CCV concept for aircraft. The CCV vehicle is assumed that it can be developed from the early state of vehicle design as well as hardware addition or modification after vehicle design. We define that the CCV mode is the additional vehicle movement based upon the independent steering input of front/rear wheel. Vehicle lateral dynamic is determined to have the steering input and control torque input. The additional vehicle modes is also defined to using CCV concept. We use right eigenstructure assignment techniques and command generator tracker to design a control law for an lateral vehicle dynamics. The desired eigenvectors are chosen to achieve the desired decoupling (i.e., lateral direction speed and yaw rate). The command generator tracker is used to ensure steady-state tracking of the driver’s command. The control objectives for the lateral dynamics achieve the ability to follow a chosen variable without significant motion change in other specified variables.

In section 2, the CCV modes for an advanced aircraft are described simply. The lateral vehicle dynamics with four wheel are described in Section 3. The mathematical formulation of the right eigenstructure assignment techniques and command generator tracker are described in section 4. The developed design is illustrated by using the lateral vehicle dynamic with four wheel in section 5. Finally, Section 6 summarizes the main results and conclusions.

2. CCV Mode for an Advanced Aircraft

As mentioned above, control configured vehicles (CCV) have been developed to provide the desired flight movement using active control technology. Active control technology make a remarkable improvement in both flight capability and maneuverability by adding new loop to traditional SISO system, that is an extended MIMO system.

The existing aircraft has been performed the rotation movement on $x$, $y$, $z$-axis and the movement of 4-degree of freedom on the airframe based on elevator, rudder and flapron. Also, aircraft has been performed the similar translation movement according to indirect control accompanied by body rotation.

On the other hand, advanced aircraft using ACT have been added $y$, $z$-direction movement in Fig. 1 which can move the direction of 6-degree of freedom independently. In order to control the additional degree of freedom, the additional control input devices must be developed in advance.

For the longitudinal dynamics of a control configured vehicle, the flapron and elevator form a set of redundant control surfaces capable of decoupling normal control forces and pitching moments. The decoupled motions include pitch pointing, vertical translation, and direct lift control. Pitch pointing is characterized by pitch attitude command without a change in flight angle, that is $\Delta \theta = \Delta \alpha$, $\Delta \gamma = 0$ where $\gamma = \theta - \alpha$, $\Delta \theta$ is the variation of pitch angle, $\Delta \alpha$ is the variation of angle of attack and $\Delta \gamma$ is the variation of flight path angle. Vertical translation is characterized by flight path command without a change in pitch attitude, that is $\Delta \gamma = \Delta \alpha$, $\Delta \theta = 0$. Direct lift con-