

Traction and Stability Control using Fuzzy-based Controller Integration

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Abstract—Adverse road conditions can cause vehicle yaw instability and loss of traction. To compensate for the instability under such conditions, corrective actions must be taken. In comparison to a mechanical differential, an electronic differential can independently control the two drive wheels and provide means of generating more effective corrective actions. As a solution for traction and stability issues in automobiles, this paper has developed a controller for a vehicle electronic differential consisting of two program-controlled rear motors. The control algorithm adjusts to changing road conditions. Traction was controlled using a motor reaction torque observer-based slip ratio estimation, and yaw stability was achieved by tracking a reference yaw rate calculated using estimated tyre cornering stiffnesses. A recursive least squares algorithm was used to estimate cornering stiffness. The yaw rate of the vehicle, as well as its longitudinal and lateral accelerations, were measured, and the body slip angle was estimated using an observer. A fuzzy inference system was used to integrate the independently developed traction control and yaw control schemes. The fuzzy inference system modifies the commanded voltage generated by the driver's input to account for the traction and yaw stability controller outputs. A vehicle simulator was used to numerically simulate the integrated controller.

Index Terms—Electronic differential, Slip control, Traction control, Stability control, Fuzzy inference system

I. INTRODUCTION

THE study of controlling vehicle dynamics to produce dependable and safer rides has recently evolved dramatically. More emphasis has been placed on creating Electronic Differentials with Traction and Stability Control (EDTSC) systems. These technologies are utilised to manage the longitudinal and lateral dynamics of the vehicle, making Electric Vehicles (EVs) safer and more robust in operation.

Because the driver's input and the control signals from the Traction and Stability Control (TSC) system must be carefully combined to have stable control over the drive train, the requirements for an EDTSC system for an EV are more demanding and sophisticated than those for internal combustion engine vehicles. This complexity, however, opens up new options for improving control over the vehicle's extremely nonlinear dynamics.

Torque vectoring has been employed by commercial EV brands to ensure optimal driving performance. The motor torque in each wheel is modified roughly 100 times per second in the torque vectoring unit [1]. Some EV manufacturers have also developed EDTSC systems to enable comfortable

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Fig. 1: Simplified representation of the proposed control architecture with Fuzzy Inference System (FIS) and Electronic Differential with Traction and Stability Control (EDTSC).

journeys in even the most adverse situations [2]. One of the most popular plug-in hybrid electric vehicles includes a traction control system with a response time 50 times faster than traditional electronic control units to improve traction and stability in critical conditions [3].

It is challenging to integrate an EDTSC system's traction and yaw stability control counterparts. The essential issue is how to ensure that longitudinal dynamics are not compromised by efforts to control lateral dynamics. This system integration issue was addressed utilising strategies such as cascaded control and model-based control. This work offers a controller integration method that uses a Fuzzy Inference System (FIS) to create corrective yaw moments utilising the predicted slip ratio and computed error in yaw rate compared to the desired yaw rate as inputs. Furthermore, a motor reaction torque observer-based slip ratio estimation is proposed while employing the Recursive Least Square (RLS) algorithm for cornering stiffness estimation.

More precisely and compactly, the contributions of this article are as follows:

- 1) Estimation of the slip ratio indirectly using the disturbance observer applied for reaction torque observance.
- 2) Using a fuzzy inference system for integration of the two controllers that address the traction and yaw rate control.

The rest of the paper is structured as follows. Section II presents a brief state-of-the-art review of TSC algorithms, and Section III discusses the vehicle dynamics model used to develop the EDTSC system. Section IV discusses the mathematical formulation of the proposed controller. Section V presents the simulation setup and results of the experiments. Section VI concludes the findings and presents the future developments.

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