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On the vehicle sideslip angle estimation through neural networks: Numerical and experimental results

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ABSTRACT

Stability control systems applying differential braking to inner/outer tires are nowadays a standard for passenger car vehicles (ESP, DYC). These systems assume as controlled variables both the yaw rate (usually measured on board) and the sideslip angle. Unfortunately this latter quantity can directly be measured only through very expensive devices however unsuitable for ordinary vehicle implementation and thus it must be estimated. Several state observers eventually adapting the parameters of their reference vehicle models have been developed at the purpose. However sideslip angle estimation is still an open issue. In order to avoid problems concerned with reference model parameters identification/adaptation, a layered neural network approach is proposed in this paper to estimate the sideslip angle. Lateral acceleration, yaw rate, speed and steer angle which can be acquired by ordinary sensors are used as inputs. The design of the neural network and the definition of the manoeuvres constituting the training set have been gained by means of numerical simulations with a 7 d.o.f.s vehicle model. Performance and robustness of the implemented neural network have subsequently been verified by post-processing the experimental data acquired with an instrumented vehicle and referred to several handling manoeuvres (step-steer, power on, double lane change, etc.) performed on various road surfaces. Results generally show a good agreement between the estimated and the measured sideslip angle.

1. Introduction

Stability control systems prevent vehicles from spinning and drifting out. Driving a car at the physical limit of adhesion between tires and road is in fact an extremely difficult task. Normal drivers usually cannot handle this situation and they lose control of the vehicle. Recently, in order to increase vehicle safety, stability control systems (ESP [1,2]; DYC [3,4]) have thus been introduced trying to control the yaw moment by applying differential braking/driving torques to the inner/outer tires.

DYC systems are based on yaw rate feedback control. In this case, the control system attempts to make the vehicle follow a desired yaw rate determined by the driver steering input and vehicle speed [3,4]. However, especially on low-friction road surfaces, preventing the vehicle sideslip angle from becoming too large is essential in order to ensure stability [1,2]. At large sideslip angles, in fact, variations of the steer angle hardly change the yaw moment, due to the non-linear relation between cornering forces and tires slip angle. Both yaw rate and sideslip angle are thus needed to implement an effective stability control system [1,2]. Unfortunately, the direct measurement of the sideslip angle is only provided by special devices (optical sensors or GPS-inertial sensors combinations), which are nowadays very expensive and however unsuitable for ordinary car

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