The Control Approach of Vehicle Steer by Wire System by Implementing Single Input Fuzzy Logic Controller

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ABSTRACT – The removal of mechanical linkage between the steering wheel and front wheel of Vehicle Steer by Wire (VSBW) system causes the traditional model-based control approaches complex and difficult to apply in practice. This paper presents investigations of single input fuzzy logic controller (SIFLC) for directional control and wheel synchronization of a VSBW system. Two SIFLC are developed for both steering wheel angle and front wheel angle. The SIFLC reduces the conventional two-input FLC (CFLC) to a single input single output (SISO) controller. The implementation environment is developed within Matlab/Simulink software for evaluation of performance in terms of input tracking capability, wheel synchronization and time response specifications.

1. INTRODUCTION

The state-of-the-art technology of VSBW system has guaranteed important enhancement in vehicle safety, stability, dynamics, manoeuvrability and comfort. Because of complete parting between steering wheel and the front wheels gives the practical problems for steering control especially on directional control and wheel synchronization of vehicle. There have been several studies in the literature reporting on VSBW control system. These studies include PID controller [1], Linear-quadratic regulator (LQR) [2] and adaptive global fast sliding mode control (AGFSMC) [3]. Furthermore, several attempts have been made to control the VSBW system by using Fuzzy logic controller (FLC). FLC is simple to control, low cost and the possibility to design without knowing the exact mathematical model of the system as known as model-free. The objective of the present work paper is to investigate the control approach for VSBW system by implementing single input fuzzy logic controller (SIFLC). The SIFLC is a simplification of the conventional FLC (CFLC) by letting the system to be SISO [4].

2. CONTROLLER DESIGN

The block diagram of the VSBW system is shown in Figure 1. The input for the system is a torque driver, T_{driver}. The motor torque, T_{M1} and torque friction, T_{frc} act as a disturbance to the system. SIFLC is responsible to compensate the error produced by steering wheel angle, θ_{sw}. Then, θ_{sw} is fed to the input of the front wheel system. The SIFLC in front wheel system will control the wheel displacement, δ_f to operate the system according to the input.

SIFLC is succeeded by applying the signed distance method [5] where the input to SIFLC is only one variable known as "distance" can be illustrated as a block diagram in Figure 2. Variable λ is the slope magnitude of the main diagonal line L_z. The distance d can be derived as Equation (1)[6]:

$$d = \frac{\dot{e} + \lambda e}{\sqrt{1+\lambda^2}} \quad (1)$$

Two system state variables e (error) and $\dot{\theta}$ (angular velocity) are selected as the feedback signal. The input to the FLC block is the distance variable d, while the output from FLC block is the change of control output $\dot{u}_0$. The final output of this SIFLC is obtained by multiplying $\dot{u}_0$ with the output scaling factor, denoted as r. The output equation can be written as in Equation (2).

$$u = \dot{u}_0 r \quad (2)$$

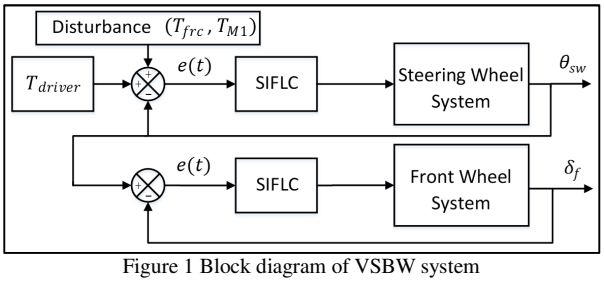

Figure 1 Block diagram of VSBW system

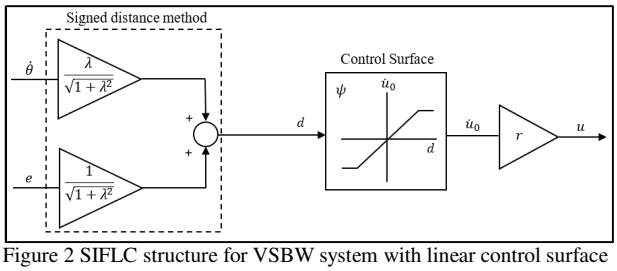

Figure 2 SIFLC structure for VSBW system with linear control surface

3. RESULTS AND DISCUSSION

Performance of the SIFLC is compared with PID-

PID as published in [1]. The result of SIFLC in Figure 3 shows that steering wheel angle can track the desired T_{driver} with zero steady state error and no overshoot compared to PID-PID controller with overshoot about 10%.

For SIFLC, the front wheel displacement angle can track the steering wheel angle well with steady state error of 0.025 radian and no overshoot which is far better than PID-PID that produced the overshoot about 19%. Both controllers have an identical settling time, Ts which is less than 1 second. But the rise time for PID-PID is faster than SIFLC.

Figure 4 shows the step response for steering wheel angle and front wheel angle with disturbance. The results indicate that the system with SIFLC produces a better response compared to PID-PID. For SIFLC, the steering wheel angle is able to track the desired input without overshoot and steady state error, but for the front wheel angle, it has a little steady state error about 0.025 radian. Meanwhile, the system with PID-PID, both steering wheel and front wheel angle can track the desired input but unable to settles with maximum residual of ± 0.15°.

From the result in Figure 5, it clearly shows that SIFLC produced better response which is it can track the desired sinusoidal input with minimal error about 0.03° compared to PID-PID, 0.1°.

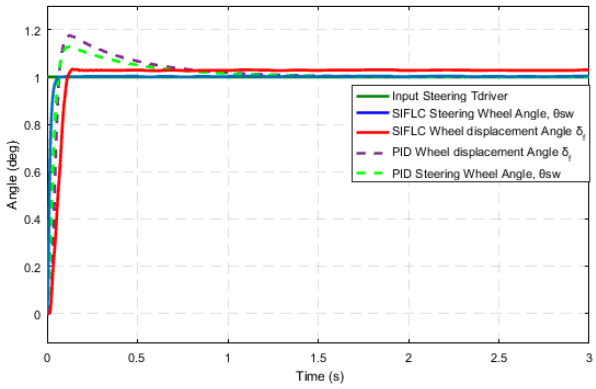

Figure 3 Step response for θ_{sw} and δ_f for SIFLC and PID-PID

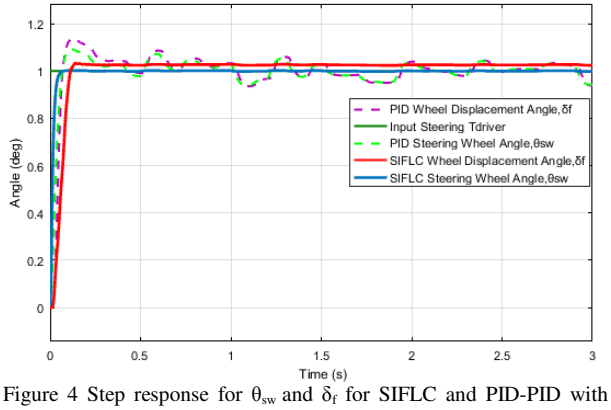

Figure 4 Step response for θ_{sw} and δ_f for SIFLC and PID-PID with disturbance.

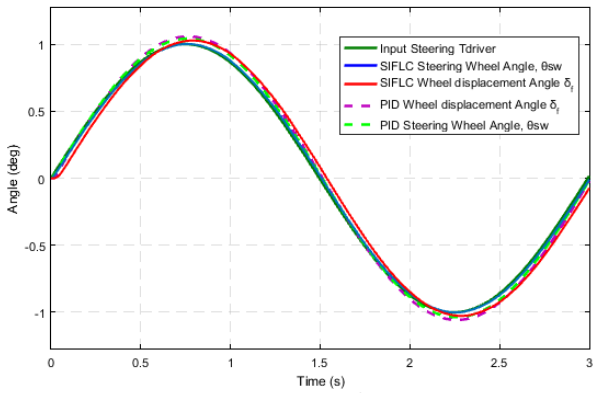

Figure 5 Sinusoidal response for θ_{sw} and δ_f for SIFLC and PID-PID.

4. CONCLUSION

Investigations into directional control and wheel synchronization of a VSBW system using SIFLC has been presented. The implementation of SIFLC requires less of design effort to tune the membership functions compared to CFLC. Finally, it is concluding that the SIFLC is capable to improve the performance of VSBW system.

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