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The Variable Steering Ratio for Vehicle Steer by Wire system Using Hyperbolic Tangent Method

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Abstract. In conventional steering system, during the parking maneuver, driver required large turned on the steering wheel to move the fornt tyre. Thus, it will increase the driver burden when turned the steering wheel. The feature of variable steering ratio (VSR), help to reduce driver burden. Moreover, it improves the vehicle maneuver at lower and high speed. This paper, proposed a control algorithm of variable steering ratio (VSR) in vehicle SBW system. The concept of hyperbolic tangent is used where it not only improved the maneuverability at lower speed, but also reduces the driver burden on the steering wheel. To investigate the effectiveness of the proposed VSR algorithm, the result is compared with conventional steering system

Introduction

The Steer by wire (SBW) system is relatively new development of modern steering system compare to the conventional steering system. It eliminated the need of mechanical linkage between the steering wheel and front wheel system and replaced with the sensors, actuator and electronic controller unit (ECU). In conventional steering system, the steering ratio is almost constant [4]. Therefore at lower speed, driver required large turn on steering wheel to turn the front tyres especially during parking manoeuvres. These increased the driver burden on the steering wheel. The variable steering ratio (VSR) is one of the advance features in vehicle SBW system. The idea of VSR is to improve the vehicle manoeuvrability and stability at low and high speed. At low speed a small steering ratio is required to increase the front tyres angle, while increasing steering ratio at high speed improve the steering stability. A fuzzy logic technique was proposed by author [3]. The consideration of lateral acceleration, yaw and velocity are taken account into adjustment of steering ratio [2]. Based on peculiarity modelling, fuzzy control theories are introduced in transmission ratio with vehicle speed and steering angle as main parameter [1].

This paper is organized as following manner. The VSR algorithms are describe in section II. The result in Section III. While section IV contains the conclusion and future works.

Variable Steering Ratio (VSR) algorithm

Commonly the average steering ratio in conventional steering system is between 12:1 to 24:1. The steering ratio affects the movement of the front tyre. A small steering ratio means that only slight turn on steering wheel, while larger steering ratio, means more turn on steering wheel are needed to turn the front tyre. In this paper, the variable steering ratio (VSR) is to adapt the overall ratio between the steering wheel angle (δ_{sw}) and front tyre angle. Fig.1 shows the VSR algorithm which is dependent on the steering angle and vehicle speed. The model of front axle system is described in [13]

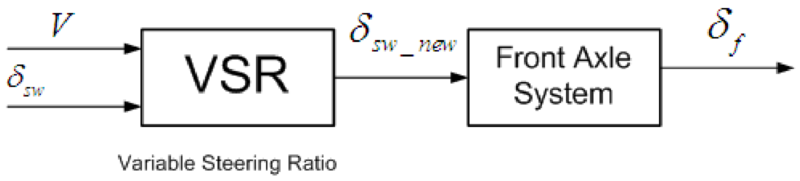

Figure 1: Variable Steering Ratio (VSR) block diagram strategy

To varying the steering ratio, the concept of hyperbolic tangent is used. The general equation of hyperbolic tangent are define in equ. 1 and the graph are shown in Fig. 2

$$\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}} \tag{1}$$

The steering ratios are formulated in (2) with (n) is a steering ratio, steering angle (δ_{sw}) and the front tyre angle (δ_f).

$$\delta_f = \frac{\delta_{sw}}{n} \tag{2}$$

By replace the steering ratio (n) with the adjustable gain (k) and the front tyre angle (δ_f) with target steering angle (δ_{sw_new}) as given in equ.3

$$\delta_{sw\_new} = \frac{\delta_{sw}}{k} \tag{3}$$

These adjustable gain (k) are determined by hyperbolic tangent in equ. 4

$$k = \frac{e^x - e^{-x}}{e^x + e^{-x}} = \tanh x \tag{4}$$

By substituting equ. (4) into (3), the final equation for VSR is shown equ.5 where V represent vehicle speed.

$$\delta_{sw\_new} = \frac{\delta_{sw}}{\left[\dfrac{e^x - e^{-x}}{e^x + e^{-x}}\right]}, \quad x = \frac{V}{10} \tag{5}$$

By neglected all the negative values for both x and y axis, the different between the VSR using hyperbolic tangent and fixed steering ratio for conventional steering system is shown in Fig. 3.

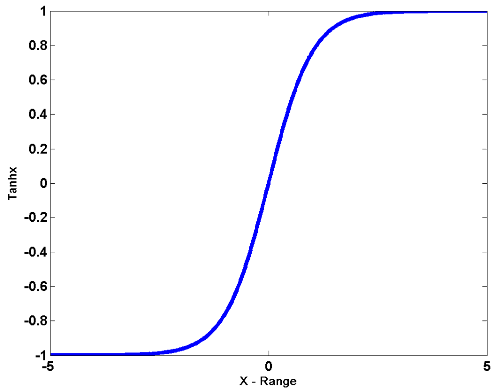

Figure. 2: Hyperbolic Tangent graph

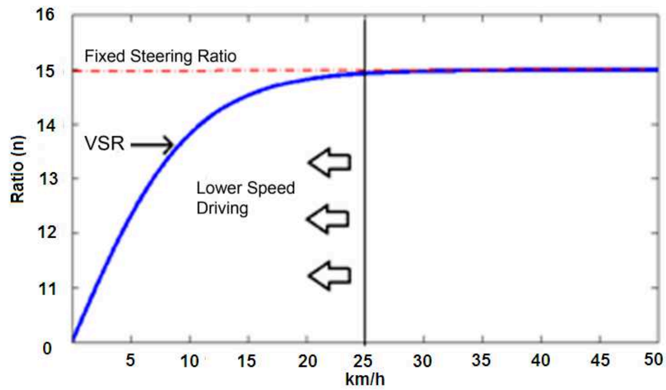

Figure. 3: Different between VSR and fixed steering ratio

Result – Variable Steering Ratio

To investigate the effectiveness of proposed VSR algorithm, the result is compare with conventional steering system [5]. A Fig.4 shows the input steering angle and vehicle speed at 10km/h for both SBW system and conventional steering system. From the result on Fig.5, the front tyre angle is increased in SBW-VSR compared to conventional steering system. Therefore, the steering ratio becomes small and increasing the front tyre angle at lower speed. These, not only reduce driver burden on steering wheel but improved the vehicle manoeuvre during parking. However, at medium and high speed of 80km/h and 120 km/h, the steering ratio are fixed and act as conventional steering system as shown in Fig. 6 and Fig. 7. Therefore, the concept of hyperbolic tangent method are help to improve vehicle maneuver especially at lower speed in SBW system.

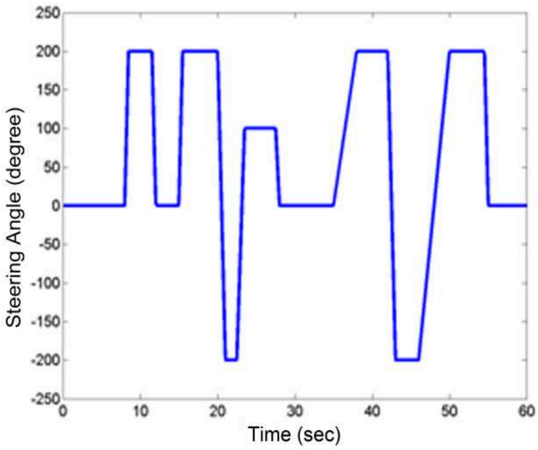

Figure.4: Steering Angle Input at lower speed

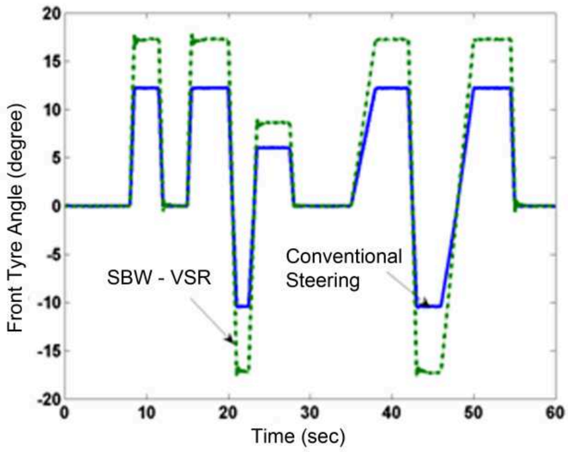

Figure.5: Front Tyre Angle at lower speed

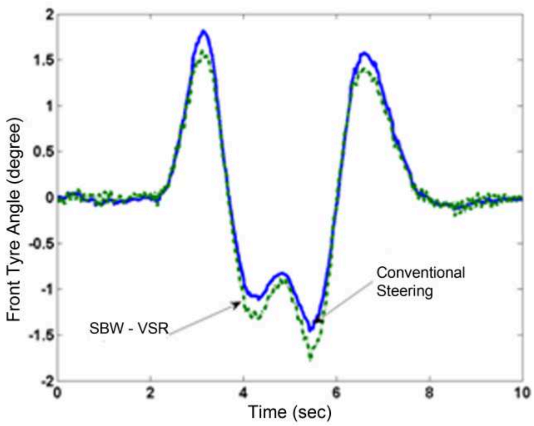

Figure.6: Steering Angle at Medium Speed

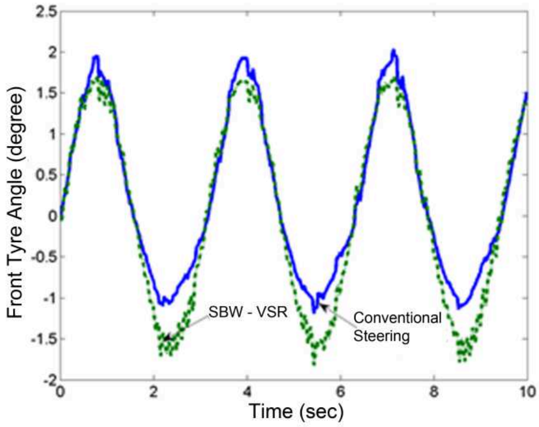

Figure.7: Front Tyre Angle at High Speed

Concluding remarks and future work.

This paper proposed the variable steering ratio (VSR) control algorithm for vehicle steer by wire system. Based on proposed VSR algorithm a hyperbolic tangent concept is introduced where depend on vehicle speed and the steering wheel angle. From the result shows, driver required less turned on steering wheel to move the front tyre. Therefore, it not only improve vehicle manoeuvre but reduce the driver burden on steering wheel especially during parking manoeuvred. In future work, the concept of hyperbolic tangent in VSR and dynamic response could be used to improve the vehicle stability especially during lane change manoeuvre.

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