Proceedings of Innovative Research and Industrial Dialogue'18, pp. XXX-XXX (July 2018)

An investigation of the lateral velocity behaviour and its effect on the trajectory generation of the autonomous non-holonomic vehicle

Muhammad Aizzat Zakaria[1,*], Baarath Kunjuni[1], Nurul Afiqah Zainal[1], Anwar P. P. Majeed[1], Umar Zakir[2]
[1]Intelligent Robotics and Vehicles, iMAMS Laboratory, Faculty of Manufacturing Engineering, Universiti Malaysia Pahang, 26600, Pekan, Pahang, Malaysia
[2]Moovita Pte Ltd, 317 Outram Road, #01-60, Holiday Inn Atrium Singapore, 169075
[*]Corresponding e-mail: maizzat@ump.edu.my

Keywords: trajectory tracking, autonomous vehicle, non-holonomic vehicle

ABSTRACT – This paper addresses the importance of consideration of the vehicle dynamics, especially when the trajectory tracking controller is subjected to an abrupt steering command from the controller. The simulation is carried out from the actual two in-wheel electric vehicle parameters. It is found out that under sudden steering change commands at different velocities, the effect of the lateral velocities becomes apparent particularly at high-speed tracking as the direction of the lateral velocity is not aligned with the direction of the vehicle's manoeuvre during the initial phase. This finding is significant in such a way that the nonlinearities of the vehicle's dynamic will cause a disturbance in trajectory tracking control and should be taken into consideration when developing a trajectory tracking control.

INTRODUCTION

The development of the trajectory tracking algorithm for the non-holonomic mobile system can be started with the mathematical modelling of the vehicle. Commonly, the trajectory tracking algorithm is developed based on several fundamental pieces of knowledge such as; geometrical technique, kinematic model, dynamic model, conventional control, adaptive control, etc.

A major assumption used in the development of the kinematic model for trajectory tracking is that the velocity vectors are in the direction of the orientation of the front and rear wheels respectively. Slip angles at both wheels were considered zero. This assumption is valid for the low-speed motion of the vehicle since the lateral force generated by the vehicle is small at low speed. However, at increased speed motion the stability of the trajectory tracking is decreased, and the vehicle tends to understeer due to the increased dynamic of the vehicle and this effect will be crucial especially for collision avoidance control [1]. Relying on the geometrically based controller is not sufficient as it will jeopardize the tracking performance under heavy disturbance.

Therefore, this paper presents the modelling behaviour of the trajectory tracking controller when it is subjected to the abrupt steering command at different velocity control. The importance of understanding the fundamental behaviour and taking it into trajectory tracking controller consideration is vital as it is found out that the uncertain dynamics attributes of the vehicle will induce a disturbance of the trajectory tracking controller [2].

The importance of addressing aforementioned effect is the predictive model of a trajectory tracking control development should be inclusive of the dynamic behaviour consideration under varying velocities to compensate the disturbance during the vehicle's navigation.

METHODOLOGY

In this research, the vehicle model parameter is obtained from the actual vehicle prototype. The vehicle is developed with two in-wheel motors at the rear tires. The sensors equipped such as Inertial Measurement Unit (IMU), odometers and GPS to measure the states of the vehicle. Figure 1 shows the vehicle model used in the research. For the full mathematical modelling derivations, the reader is directed to our previous paper for the details of the parameters used [3].

Figure 1 The two in-wheel vehicle prototype with sensors used in the research to obtain the vehicle parameters.

1.1. Simulation setup

In order to analyse the effect of the lateral velocity when an abrupt steering command is given at time equal to 65 seconds as in Figure 2. The vehicle trajectory is manoeuvred at different initial velocity. Since our vehicle cannot exceed 30 km/h; the speed of the test is limited to 30 km/h to ensure the validity of our model with the actual vehicle. Five different speeds are provided as the inputs; 5 km/h, 10 km/h, 20 km/h, 30 km/h. Since the vehicle's velocity is formed by the two in-wheel motors, the PID control is used to compensate the speed control of both tires by controlling the amount of the input voltage going to the motors.

RESULTS AND DISCUSSION

Figure 3 shows the response of the vehicle's velocity in the longitudinal direction when it is being controlled by a PID control system for both tires independently. The PID control maintains its constant velocity at the desired speed respectively (5 km/h, 10 km/h, 20 km/h, 30 km/h). At 65 seconds, when the steering command varies its magnitude, it is observed that the longitudinal velocity is being decreased as the lateral velocity is produced due to the steer angle difference.

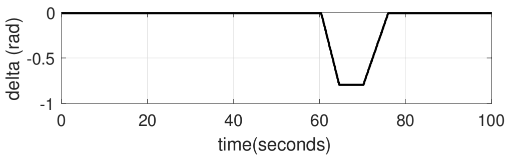

Figure 2 Steering input commands

Due to steering difference, the lateral velocity is generated as in Figure 4. It is observed at the low-speed velocity, the effect of the abrupt steering change command almost negligible as the direction of the lateral velocity generated is in the same direction as the steering commands direction. However, the effect of the lateral velocity is significant when it is at high velocity although the yaw rate is settled in the same direction as in the vehicle's steer motion (see Figure 5).

CONCLUSIONS

From the results, it is found out that the consideration of the vehicle dynamics during the controller development is necessary as the effect is significant notably during abrupt steering deviation in the trajectory tracking controller at the high-speed navigation. When this effect is neglected, the trajectory tracking controller may become unstable under a critical manoeuvre.

ACKNOWLEDGEMENT

The authors would like to thank Dr Heerwan Piee from the Vehicle Dynamics Laboratory, Universiti Malaysia Pahang for the vehicle prototype development and advice. The research is financially supported by a research grant no. RDU170371 from Universiti Malaysia Pahang.

REFERENCES

[1] U. Z. A. Hamid *et al.*, "Autonomous emergency braking system with potential field risk assessment for frontal collision mitigation," in *Systems, Process and Control (ICSPC), 2017 IEEE Conference on*, 2017, pp. 71–76.

[2] M. A. Zakaria, H. Zamzuri, and S. A. Mazlan, "Dynamic Curvature Steering Control for Autonomous Vehicle: Performance Analysis," in *IOP Conference Series: Materials Science and Engineering*, 2016, vol. 114, no. 1, p. 12149.

[3] K. Baarath, M. A. Zakaria, and N. A. Zainal, "An Investigation on the Effect of Lateral Motion on Normal Forces Acting on Each Tires for Nonholonomic Vehicle," *Lect. Notes Mech. Eng.*, vol. 1, no. 1, 2018.

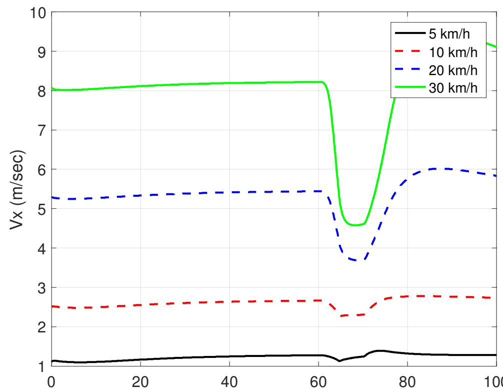

Figure 3 Longitudinal velocity controlled by the PID

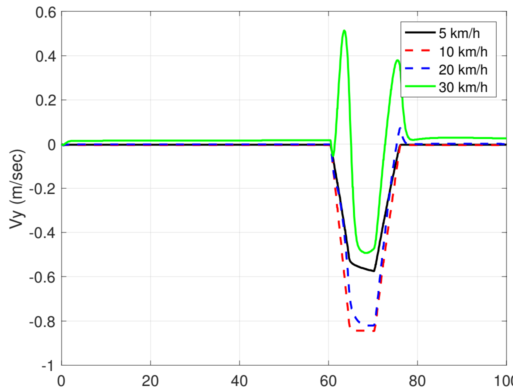

Figure 4 Lateral velocity response of the vehicle

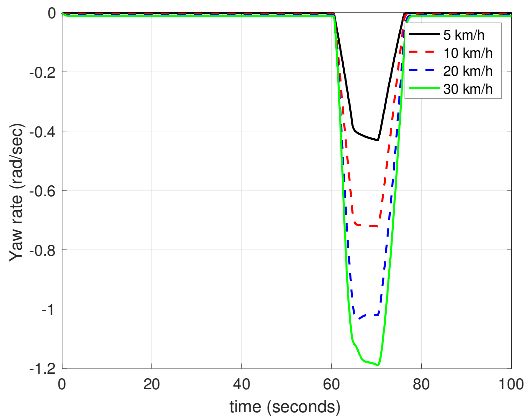

Figure 5 Yaw rate response of the vehicle