講演番号	091

文献番号	20226091

Speed planning method for autonomous driving considering front/rear tire force and yaw moment

Takatsugu Oda[1)] **Yuya Niwa[1)]** **Masayasu Shimakage[1)]** **Kenichi Seki[1)]**
Naoki Miyashita[1)] **Yuki Shiozawa[1)]**

1) NISSAN MOTOR CO.,LTD., Nissan Research Center
1-1 Aoyama Morinosato, Atsugi, Kanagawa, 243-0123, Japan

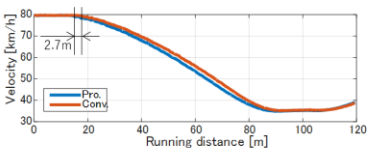
KEY WORDS: **Electronics and control, autonomous driving, motion control,** Speed planning (E1)

Autonomous vehicles on suburban roads often need to follow fast traffic flow and complex corners with turnarounds. Autonomous driving in such an environment requires driving in a high G-range in accordance with the surrounding traffic flow. However, conventional vehicle speed planning methods assume that the curvature and vehicle speed change slowly over time during driving. Thus, when conventional methods are applied to suburban roads, the vehicles may enter a corner at a higher speed than that suitable for turning, resulting in a deviation from the target path. This can be explained by the "yaw moment" and "tire nonlinearity," which have not been widely discussed in conventional speed planning methods. Although these are well known in the field of vehicle motion control, few studies have incorporated them into speed planning. This study proposes a vehicle speed planning method that takes these factors into consideration to solve this issue.

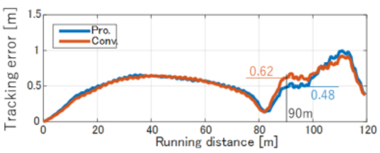
First, to incorporate the tire force required to generate the yaw moment in vehicle speed planning, the vehicle speed needs to be reduced transiently during cornering, and the acceleration and deceleration rates need to be limited. Driving on suburban roads is characterized by rapid changes in vehicle orientation over time, which is, the yaw rate. Therefore, the yaw moment required to change the yaw rate is typically greater than that required for driving in urban areas. In most earlier studies, the achievable upper speed limit was calculated based on the steady-state relationship between the curvature of the travel path and the lateral acceleration of the center of gravity while turning. However, few studies have focused on cornering during which the yaw moment is generated. For feasible speed planning of a vehicle during cornering, the key factor is how each tire, which actually generates the force, affects the longitudinal/horizontal/rotational acceleration of the center of gravity of the vehicle within the friction circle. Because the yaw moment required to travel the target path is determined by the changes in the curvature of the path and vehicle speed, the sufficient yaw moment may not be generated simultaneously with the maximum centripetal force. Accordingly, a vehicle speed planning method is proposed so that the centripetal force and yaw moment required for driving are within the possible range of generation.

Next, the acceleration and deceleration rates are limited to prevent extreme deflections in the tire workload, which may lead to fluctuations in the vehicle performance. This ensures, for example, that when decelerating toward a corner, braking occurs earlier allowing the vehicle to enter the corner with sufficient deceleration. A tire can generate a lateral force proportional to the sideslip angle in the low tire sideslip angle range; however, as the sideslip angle is increased to generate a greater lateral force, the linearity deteriorates gradually, eventually resulting in the saturation of the lateral force beyond a certain sideslip angle. Driving on suburban roads requires the use of the nonlinear region of the tire force curve to generate large acceleration; however, if one of the front or rear tires is in the nonlinear or saturated region, the vehicle's turning characteristics will change and may cause a deviation from the target path. Such nonlinear characteristics are also observed when longitudinal and lateral forces are simultaneously generated in the tire and when the loads on the front and rear tires fluctuate owing to acceleration and deceleration. Therefore, a vehicle speed plan that can prevent deviation from the target path can be realized by setting an upper limit on the tire workload of the front and rear tires and calculating the vehicle speed from the centripetal force and acceleration/deceleration rate that can be generated within that range.

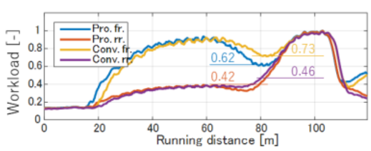
The proposed method was evaluated through simulations and experiments during a single corner entry at a high turning G. The simulation for the evaluation of the first factor showed that the target vehicle speed was within the possible range of the front/rear tire forces using the proposed method. Next, the evaluation of the second factor showed that an earlier initiation of deceleration toward the corner can prevent the use of the nonlinear tire behavior. Finally, Fig. 1 shows the results of these effects, confirmed via an evaluation using a real vehicle. Fig. 1 (a) shows that the braking timing was approximately 2.7 minutes ahead. This allows the front tires to generate a force that produces a yaw moment upon corner entry, resulting in an approximately 23% reduction in the path-following error at the 90 m point during the turn, as shown in Fig. 1 (b). The deflection in the front and rear tire workload decreased, as shown in Fig. 1 (c), which may be due to the reduction in the fluctuation of the turning characteristics of the vehicle. In conclusion, the proposed method helps solve the issues of concern in a high G-range and improves the path-following performance.



(a) Velocity



(b) Tracking error



(c) Tire workload

2022 JSAE Congress (Autumn) - Summarized Paper
Issued on October 7, 2022