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Influence of determining the normal reaction on the autonomous vehicle motion

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INTRODUCTION

The primary goal of automating the driving process is to enhance road safety. However, several technical challenges and technological barriers must be addressed before level 4 (high automation, according to the SAE classification) vehicles can become commercially available.

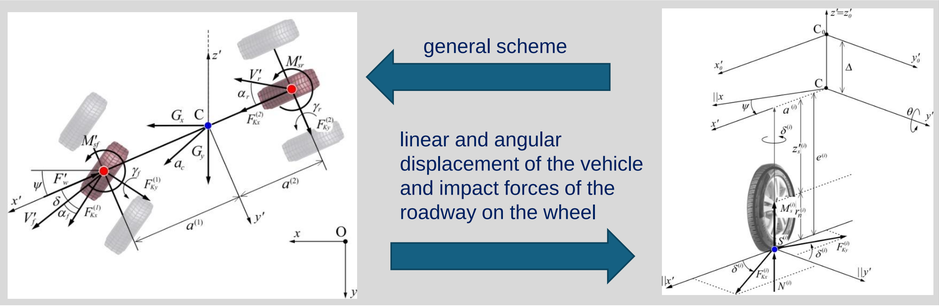
The dynamic models used in motion planning for autonomous vehicles must meet specific requirements. The model must exhibit numerical efficiency, meaning that computations should be performed in a short period of time. At the same time, the model should accurately represent the actual kinematic and dynamic properties of the vehicle.

The paper focuses on the modeling of vehicle dynamics. It presents the impact of the method used to determine normal reactions on the motion of an autonomous vehicle. A model with 5 degrees of freedom, formulated in **two** variants, was considered.

MATERIALS, METHODS & IMPLEMENTATION

The 5 degrees of freedom model is a planar model that considers two translations of the body center of gravity x_c, y_c, yaw angle ψ and the angles of rotation of the substitute front and rear wheels. With the model formulated in the roadway system, the generalized coordinates are the components of the vector:

$\mathbf{q}^{\mathrm{T}} = [x_c \quad y_c \quad \psi \quad \gamma^{(1)} \quad \gamma^{(2)}]$



RESULTS

Variant I. In the classical approach (Dallas et al, 2020), reactions $N^{(1)}, N^{(2)}$ are determined in a simplified manner from the equations:

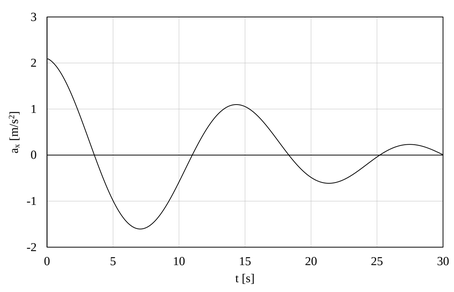
$N^{(1)} = G_z \frac{a^{(2)}}{L}, N^{(2)} = G_z \frac{a^{(1)}}{L}$

Variant II enables the vertical displacement of the body and the roll angle to be considered, without having to increase the number of degrees of freedom of the model. Coordinates of a point $S^{(i)}$ – located at the wheel/roadway contact area can be defined as: $\Delta^{(i)} = -\theta a^{(i)} + \Delta$, then:

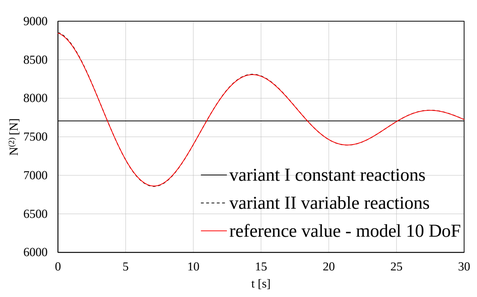
$N^{(i)} = -c^{(i)}\Delta^{(i)} = -c^{(i)}\left[-\theta a^{(i)} + \Delta\right] = c^{(i)}\left(\theta a^{(i)} - \Delta\right)$. To determine the values Δ, θ two additional equilibrium equations are formulated.

Simulation I acceleration assumed to be a known function of time

acceleration course



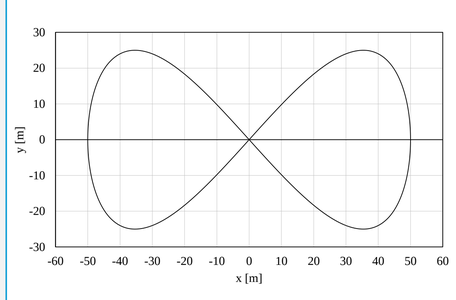
normal reactions at the rear substitute wheel of the vehicle



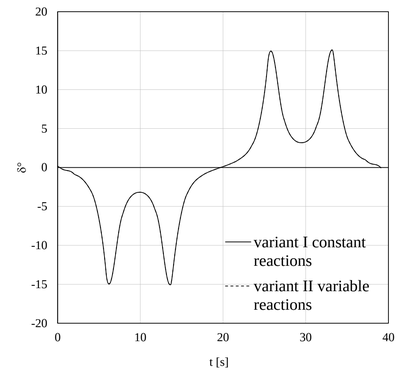
I the normal reactions are $N^{(1)} = 9636\,N, N^{(2)} = 7707N$. Results from variant II shows that the force distribution changes during vehicle movement.

Simulation II path following task

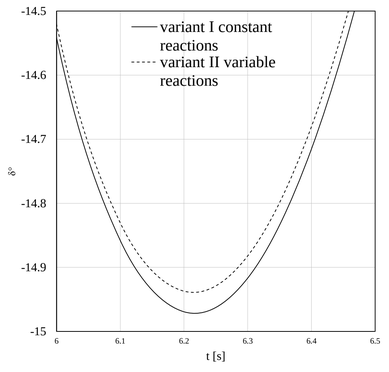
Considered path



Calculated steering angle course



enlargement



The variant of determining normal reactions has not significantly influenced the selected steering angle. However The slight difference is noticeable

CONCLUSION & IMPLEMENTATION PATH

The consideration of normal reactions in a variable manner allows for a more accurate representation of the vehicle's trajectory. Tests with the control algorithm indicate that even during low-acceleration manoeuvres, a small difference in vehicle movement is observed. Therefore, it appears valuable to explore the applicability of the model with variable reactions in the context of emergency braking manoeuvres. The following conclusions can be drawn from the above:

- Consideration of the longitudinal roll angle θ and, the center of mass deflection Δ enables more accurate determination of the normal reactions,
- In analyzed cases, the method of determining normal reactions has a small effect on the movement of the Vehicle,
- The change in the method of determining the normal reactions results in increase of calculation time from 3.00 s (variant I) to 3.21 s (variant II).

In future work, it is planned to use a model with 5 degrees of freedom in a variant with variable forces in the motion planning tasks of an autonomous vehicle such as:

- lane change,
- emergency breaking maneuvers.

ACKNOWLEDGEMENTS