## Parameter identification of a multibody vehicle model using mathematical optimization

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## Abstract

Models of real-life mechanical systems often have parameters difficult to measure, calculate or estimate. Even if they can be measured, the process might involve disassembling, which is always costly and laborious. Furthermore, some parameters in the field of vehicle dynamics, such as the torsion stiffness coefficient of the chassis, cannot be calculated without a probably destructive torsion test or with a detailed finite element model of the complete assembly. Therefore, a systematic identification of such parameters using experimental data is highly desirable.

In this paper, the parameters are estimated by the minimization of a mathematical cost function defined as:

$$\min_{b} \Psi_{0} = \sqrt{\int_{t_{i}}^{t_{f}} \left[ \left( \hat{x} - x \right)^{2} + \left( \hat{y} - y \right)^{2} + \left( \hat{z} - z \right)^{2} + \left( \hat{\varphi} - \varphi \right)^{2} + \left( \hat{\theta} - \theta \right)^{2} + \left( \hat{\psi} - \psi \right)^{2} \right] dt}$$
(1)

which is the root mean square (RMS) value of the difference between the position responses of the model – all translational and rotational bodywork position variables that depend on t,  $\mathbf{z}$ ,  $\dot{\mathbf{z}}$ ,  $\ddot{\mathbf{z}}$  and  $\mathbf{b}$  – and the experimental results obtained doing a particular maneuver – which are indicated with the *hat* symbol– and only depend on time  $t, \mathbf{z}, \dot{\mathbf{z}}$ ,  $\ddot{\mathbf{z}}$  are the position, velocity and acceleration of the independent coordinates of the model and  $\mathbf{b}$  is the set of parameters to identify.

The process of the optimization loop is depicted in Figure 1. First of all the objective function and its gradient are evaluated. Therefore, the forward dynamics and the state sensitivities have to be computed. For the former, a semi-recursive method based on a double step Maggi's formulation is used 0. The sensitivity analysis is carried out with a hybrid direct-automatic differentiation method which combines the Direct Differentiation Method (DDM) [2] and Automatic Differentiation techniques (AD) **;Error! No se encuentra el origen de la referencia.** This approach allows computing algorithmically all the terms that would otherwise need to be computed manually. Once solved the forward dynamics and the sensitivity analysis, the evaluation of the object function and of its gradient is direct.

In order to obtain a realistic solution some optimization constraints are added: grip, wheel contact and box constraints. Grip constraints are based on Pacejka's model **;Error! No se encuentra el origen de la referencia.** of the side force,  $F_y$ , and is formulated so that the slope of that force w.r.t the side slip angle,  $\alpha$ , is always positive. The wheel contact condition formulation is used to enforce positive values of the tire normal forces. Finally, box constraints are imposed on the designed variables in order to prevent unrealistic parameter values.



Figure 1: Flowchart of the optimization loop

This method is applied to an IVECO Daily 35C15 industrial van modeled in **¡Error! No se encuentra el origen de la referencia.** Several maneuvers have been performed in order to obtain the necessary experimental data for the parameter identification process: speeding and braking maneuvers with different maximum speeds; circular maneuvers at different speeds; and maneuvers with speed bumps in order to excite the roll movement or the pitch movement.

This method allows identifying the parameters of the model in a rather automatic way by means of using the aforementioned hybrid direct-automatic differentiation method. It also yields to estimate correctly the model's parameters validating therefore the mathematical model of the vehicle dynamics.

## References

- [1] García de Jalón, J.; Callejo, A.; Hidalgo, A.F.: Efficient solution of Maggi's equations. Journal of Computational and Nonlinear Dynamics, 2011, DOI: 10.1115/1.4005238.
- [2] Gutiérrez-López, M. D.; Callejo, A.; García de Jalón, J.: Computation of independent sensitivities using Maggi's formulation, The 2nd Joint International Conference on Multibody System Dynamics, Stuttgart, Germany, 2012.
- [3] Pacejka, H.B.: Tyre and Vehicle Dynamics, Butterworth-Heinemann, ISBN 0-7506-5141-5, 2002.
- [4] A. F. Hidalgo, Simulación en tiempo real de vehículos industriales con modelos multicuerpo de gran complejidad, *Doctoral Thesis*, 2013.