# Parameter Identification of A Double Wishbone Suspension System Using The Homotopy Optimization

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## EXTENDED ABSTRACT

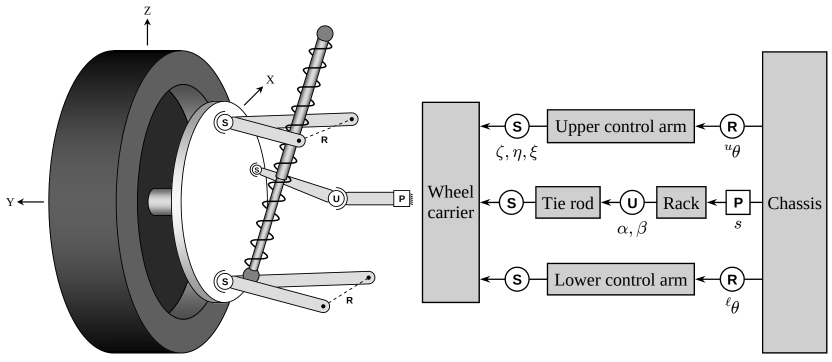
## 1 Introduction

Identifying the parameters of physics-based models of dynamical systems is essential in proper modeling of real-world systems. Experimental input-output data measurements along with optimization procedures are used to estimate parameters appearing in the model equations that are not known a priori. Furthermore, reducing the size of high-fidelity models, which is essential in real-time application and control-oriented problems, would generate unknown parameters to be identified.

Performance of Homotopy optimization procedure in parameter estimation of dynamical systems has been studied in previous research works for simple multibody systems [1], a reduced-order vehicle dynamic model [2], and an electrochemistry battery model [3]. However, effectiveness of the method was not examined for complicated multibody systems with highly nonlinear differential equations, coupled with algebraic constraints. Accordingly, parameter identification of a double wishbone suspension system using homotopy optimization is considered in this work. The key feature of the proposed procedure is guiding the algorithm to a global minimum of the objective function, which is one of the main issues in optimization problems.

## 2 A Double Wishbone Suspension System Model

Multibody model of the double wishbone suspension shown in Figure 1 was derived and used for model reduction and kinematic analysis purposes [4, 5]. The suspension response to road input profiles applied at the wheel is particularly complex as there are several joints of different types (spherical, universal, and revolute) in the double wishbone suspension, connecting the upper and lower control arms, the tie rod, and rack to the chassis and the wheel carrier. Figure 1(b) shows a topological graph of the suspension system, including components and joints variables in the model.



(a) (b)

Figure 1: Schematic of the single double-wishbone suspension system (a) and its corresponding topological graph (b).

MapleSim software is used to simulate the multibody dynamic model of a vehicle system with double-wishbone front suspensions and trailing arm rear suspensions, keeping the parameters of the suspension systems symbolic. Results from the high-fidelity simulation model with original parameters of the double wishbone suspension system, embedded in the full vehicle model using graph-theoretic approach developed by the software, are applied as the basis for parameter identification. Equations governing the dynamic behavior of the system are highly nonlinear, coupled, and in Differential-Algebraic Equations (DAEs) form, i.e. equation (1), which challenges effectiveness and stability of the optimization scheme. Considering the symbolic parameters to be identified in a vector, the equations can be expressed as

$$\boldsymbol{\Psi}\dot{\boldsymbol{x}} = \boldsymbol{f}(\boldsymbol{x}(t), \boldsymbol{u}(t), \boldsymbol{\Gamma}, t) \tag{1}$$

in which $\boldsymbol{\Gamma}$ is the vector of parameters, $\boldsymbol{x}(t)$ is states of the model, and $\boldsymbol{u}(t)$ is input to the system. It should be noted that $\boldsymbol{\Psi}$ is singular due to algebraic constraints.

## 3 Homotopy optimization scheme

Approaching the global minimum of an objective function is a very challenging issues in the optimization process of parameter identification problems. In homotopy optimization scheme, the mathematical model of the system is modified by coupling the original differential equations to the experimental data using the homotopy parameter, as shown in equation (2) .

$$\boldsymbol{\Psi}\dot{\boldsymbol{x}} = \boldsymbol{f}(\boldsymbol{x}, \boldsymbol{u}, \boldsymbol{\Gamma}, t) + \vartheta K_i(\boldsymbol{x}_{\mathrm{exp}} - \boldsymbol{x}) \tag{2}$$

where $\vartheta$ is the homotopy parameter, decreasing from 1 to 0 during the optimization process, and $K_i$ is a gain ensuring that simulation trajectory tracks the experimental data when $\vartheta = 1$. In this paper, simulation results from the high-fidelity vehicle model with a set of predefined parameters of the double wishbone suspension is considered as the basis for experimental data. The objective function to be minimized is represented in the following quadratic form:

$$\boldsymbol{\Upsilon}(\boldsymbol{\Gamma}) = \frac{1}{2}\sum_{j=1}^{n}\left\{\int_0^{T_s}\left(\boldsymbol{x}^j_{\mathrm{exp}} - \boldsymbol{x}^j(\boldsymbol{\Gamma}, t)\right)^2 \mathrm{d}t\right\} \tag{3}$$

## 4 Results & Conclusion

In this research work, the focus is to identify equivalent parameters from the geometric dimensions of the upper and lower control arms, which are used to define local frames connecting these components to the other parts of the suspension system. Lateral speed of the vehicle chassis is considered as the output experimental data, extracted from simulation of the rigorous vehicle model in a single-lane-change maneuver, and is coupled to the original differential equations of the system, as described in equation (2). Simulation results with the original parameter and identified parameters of the suspension system are shown in Figure 2.

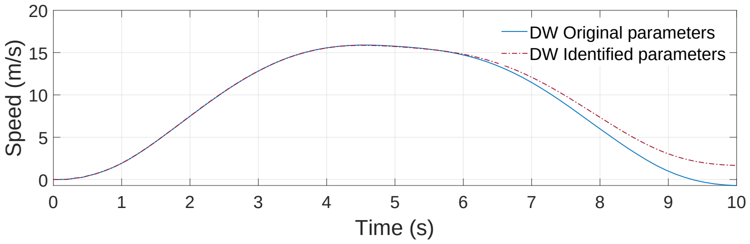


Figure 2: Simulated time history of lateral speed of the chassis in the high-fidelity vehicle model using original and identified parameters for the double wishbone suspension system.

Promising results were obtained, when equivalent length and width of the upper control arm in the front suspension system were targeted in the identification process with a maximum error of 5% for the identified parameters.

## References

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