

# Multi-Body Simulation and Multi-Objective Optimization Applied to Vehicle Dynamics

Fabiano Maggio<sup>1,\*</sup>

<sup>1</sup> EnginSoft S.p.A., Via Giambellino 7, 35129, Padova, Italy

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**Abstract** – This paper describes a demo application, where modeFRONTIER, a commercial software for design optimization, is coupled with a parametric 2D Multi-Body model of a touring motorcycle. The optimizer is asked to identify the characteristics of the front suspension (telelever scheme) that deliver more safety, more stability, and more riding comfort for a braking maneuver in straight running. All objectives are described through 4 scalar indexes, extracted from the braking kinematics.

As expected, results highlight that trade-off relationships connect the objectives. Only 13, among the 1900 tested configurations, are able to simultaneously improve the 4 indexes. Moreover, no design in this selection assures a decisive improvement of the stability. In order to accomplish this priority requirement, the best design is chosen accepting a slight reduction of stability.

**Key words:** Motorcycle Optimization, Braking Maneuver, Telelever, Multi-Objective Optimization, Design Optimization

## 1 Introduction

Dynamical performances of two wheeled vehicles largely depend on the response of each component. Among all components, tires and suspensions are the most important sub-systems, because their role is to modulate any force going from the road to the chassis [1, 2, 3, 4]. Therefore, a deep knowledge of such parts can be the turning key to develop better and safer motorcycles.

Multi-Body Simulation is the most suitable approach to perform vehicle dynamics investigation [5, 6, 7]. By creating parametric models, different configurations can be quickly evaluated, even at the earliest stage of the entire development process. From a business perspective, this means that wrong gateways can be dropped long before they lead to costly and useless real prototypes.

These benefits can be further increased by coupling the Multi-Body Simulation software with modeFRONTIER, which automatically plans and drives sets of simulations in order to perform complex tasks such as Design of Experiment, Parameter Sensitivity Analysis, and Multi-Objective Optimization.

This paper describes a demo application, where modeFRONTIER is asked to identify the parameters of a motorcycle front suspension to deliver more safety, more stability, and more riding comfort for a braking maneuver in straight running. Although the research is targeted to a very specific case, the proposed methodology can be straightforwardly extended to any user-defined running condition. Potentially, it is possible to build a single modeFRONTIER project to optimize different vehicle parts for various maneuvers.

As expected, results highlight that trade-off relationships connect the objectives, hence full optimization is almost impossible. Only 13, among the 1900 tested configurations, are able to simultaneously improve the 4 scalar indexes that have been previously defined to measure the objectives.

Moreover, no design in this selection promises a decisive improvement of the stability. In order to meet these primary requirements, the best design is chosen accepting a slight reduction of stability. The decision task has been totally supported by the Multi Criteria Decision Making tool implemented in modeFRONTIER.

## 2 The 2D Motorcycle Model

The Motorcycle is a complex multi-body system and special efforts are necessary to reliably simulate the overall dynamics. The broad range of literature available on this topic covers all simulation fields, such as time domain behavior [6, 7], optimal maneuver [8, 9], steady trim [10], frequency response [11], modal properties [5, 14, 15], tire dynamics [12], and so on. Since this research aims at highlighting the benefits of implementing an optimizer into the simulation chain, a detailed and validated model is not available. Model features have been implemented following state-of-art guidelines [13] to ensure sufficient result reliability.

As a simple test case, the vehicle behavior at braking during straight line motion is considered. In general, lateral dynamics plays an important role and a detailed 3D model would be recommended to perform thorough investigation. However, a 2D model includes enough features to study the influence of the front suspension on the braking distance, keeping the simulation complexity at reasonable level. Indirect considerations on stability and vehicle comfort can be made in any event by examining the variation of some in-plane quantities [4, 14].

The motorcycle model used in this research consists of 7 rigid bodies, such as chassis (which includes the rider), rear wheel, swinging arm, front wheel and three bodies for the front suspension with telelever scheme. Bodies are connected using proper joints to obtain the exact number of in-plane degrees of freedom.

\* Corresponding author: [fmaggio@enginsoft.it](mailto:fmaggio@enginsoft.it)

# Multi Body Simulation And Multi Objective Optimization

**Antonio J. Tallón-Ballesteros**



## **Multi Body Simulation And Multi Objective Optimization:**

**7th International Munich Chassis Symposium 2016** Prof. Dr. Peter E. Pfeffer, 2016-08-15 In chassis development the three aspects of safety vehicle dynamics and ride comfort are at the top of the list of challenges to be faced Addressing this triad of challenges becomes even more complex when the chassis is required to interact with assistance systems and other systems for fully automated driving What is more new demands are created by the introduction of modern electric and electronic architectures All these requirements must be met by the chassis together with its subsystems the steering brakes tires and wheels At the same time all physical relationships and interactions have to be taken into account *Computational and Experimental Studies* Y. Villacampa, G.M. Carlomagno, S. Ivorra, C. A. Brebbia, 2018-03-28 Comprising specially selected papers on the subject of Computational Methods and Experimental Measurements this book includes research from scientists researchers and specialists who perform experiments develop computer codes and carry out measurements on prototypes Improvements relating to computational methods have generated an ever increasing expansion of computational simulations that permeate all fields of science and technology Validating the results of these improvements can be achieved by carrying out committed and accurate experiments which have undertaken continuous development Current experimental techniques have become more complex and sophisticated so that they require the intensive use of computers both for running experiments as well as acquiring and processing the resulting data This title explores new experimental and computational methods and covers various topics such as Computer aided Models Image Analysis Applications Noise Filtration of Shockwave Propagation Finite Element Simulations **Proceedings of InCoME-VI and TEPEN 2021** Hao Zhang, Guojin Feng, Hongjun Wang, Fengshou Gu, Jyoti K. Sinha, 2022-09-17 This volume gathers the latest advances innovations and applications in the field of condition monitoring plant maintenance and reliability as presented by leading international researchers and engineers at the 6th International Conference on Maintenance Engineering and the 2021 conference of the Efficiency and Performance Engineering Network InCoME VI TEPEN 2021 held in Tianjin China on October 20 23 2021 Topics include vibro acoustics monitoring condition based maintenance sensing and instrumentation machine health monitoring maintenance auditing and organization non destructive testing reliability asset management condition monitoring life cycle cost optimisation prognostics and health management maintenance performance measurement manufacturing process monitoring and robot based monitoring and diagnostics The contributions which were selected through a rigorous international peer review process share exciting ideas that will spur novel research directions and foster new multidisciplinary collaborations **Fuzzy Systems and Data Mining V** Antonio J. Tallón-Ballesteros, 2019-11-15 The Fuzzy Systems and Data Mining FSDM conference is an annual event encompassing four main themes fuzzy theory algorithms and systems which includes topics like stability foundations and control fuzzy application which covers different kinds of processing as well as hardware and architectures for big data and time series and has wide applicability the interdisciplinary

field of fuzzy logic and data mining encompassing applications in electrical industrial chemical and engineering fields as well as management and environmental issues and data mining outlining new approaches to big data massive data scalable parallel and distributed algorithms The annual conference provides a platform for knowledge exchange between international experts researchers academics and delegates from industry This book includes the papers accepted and presented at the 5th International Conference on Fuzzy Systems and Data Mining FSDM 2019 held in Kitakyushu Japan on 18 21 October 2019 This year FSDM received 442 submissions All papers were carefully reviewed by program committee members taking account of the quality novelty soundness breadth and depth of the research topics falling within the scope of FSDM The committee finally decided to accept 137 papers which represents an acceptance rate of about 30% The papers presented here are arranged in two sections Fuzzy Sets and Data Mining and Communications and Networks Providing an overview of the most recent scientific and technological advances in the fields of fuzzy systems and data mining the book will be of interest to all those working in these fields

*Airdrop Recovery Systems With Self-Inflating Airbag* Hongyan Wang, Qiang Rui, Huangjie Hong, Jianyang Li, 2017-06-13 A complete reference text to airdrop recovery systems with self inflating airbags focusing on analysis test data and engineering practicalities Comprehensively covers the fundamental theories design matching and analysis of airdrop recovery systems that include a parachute and self inflating airbag system Gives step by step guidance to aid readers in analyzing and designing their own recovery systems Highlights advanced research programs in the field of airdrop recovery systems such as simulation and optimization methods

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**The Dynamics of Vehicles on Roads and Tracks** Martin Rosenberger, Manfred Plöchl, Klaus Six, Johannes Edelmann, 2016-03-30 The IAVSD Symposium is the leading international conference in the field of ground vehicle dynamics bringing together scientists and engineers from academia and industry The biennial IAVSD symposia have been held in internationally renowned locations In 2015 the 24th Symposium of the International Association for Vehicle System Dynamics IAVSD

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