

## Massimo Guiggiani: The science of vehicle dynamics: handling, braking, and ride of road and race cars

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Francesco Biral 

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**Abstract** Guiggiani’s book titled “The Science of Vehicle Dynamics. Handling, Braking, and Ride of Road and Race Cars” is an excellent contribution to the comprehension of vehicle dynamics both for undergraduate students and experts in the field. Despite 50 years of books on vehicle dynamics, this work has the merit to propose new concepts and interpretations with its rigorous approach which does not leave nothing either to mere intuition or for granted.

**Keywords** Vehicle dynamics · Handling · Race cars

In the last fifty years many books about vehicle dynamics have been published. A proper classification based on contents and explanation approaches may be difficult. However, one possible grouping based on contents could be: (a) understanding the physical principles of vehicle dynamics and their implication on vehicle modelling, simulation and performance analysis [3, 4, 6–11, 13, 15–19, 21, 23], (b) vehicle dynamic analysis oriented to control design and development of intelligent systems for driving support

[1, 2, 5, 14, 20, 22, 24, 25], (c) description of vehicle bodies and components [9, 10, 12].

The book of Prof. Massimo Guiggiani falls in the first category but set the basis for a sound comprehension of vehicle dynamic topics which is useful in automotive control design with great care in highlighting result applicability and model limitations. Differently than many other books, it assumes that the reader has a prior background knowledge of laws of kinematics and mechanics and does not provide any primer on multibody modelling. In my opinion this is a point of appreciation since the book only focuses on the vehicle dynamic topics without digressions that may hinder the main topic explanations. The book covers the classical subjects of the discipline but it applies the concepts developed to the racing vehicles in some dedicated chapters with interesting remarks and examples. The book is organised in 10 chapters starting with an introduction where the author states that the aim of the book is the formulation of “vehicle dynamics based on sound concepts, with clear definitions, modelling and rigorous mathematical analysis”.

The first chapter addresses the essence of the wheel-tyre mechanics avoiding the use of detailed physical model (such as the brush model) whose complete description is moved to the last chapter. Indeed this is a good choice that eases the tyre characteristics description introducing the main concepts to be used in the following chapters without the burden of the involved

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F. Biral (✉)  
Department of Industrial Engineering, University of  
Trento, Via Sommarive 9, 38123 Trento, Italy  
e-mail: francesco.biral@unitn.it

calculations that develops from the brush model theory.

Chapter 3, which is the largest, is dedicated to the derivation of a vehicle model which is subject to a pure planar motion. The chapter is clear and well organised and can be followed by readers in a manner that it allows the actual construction and derivations of the model equations. It starts from the kinematics of the centre of mass and of the contact points. The Newton Euler equations are used to derive the overall vehicle equations of motion and the overall lateral and longitudinal load transfer conditions. The author introduces the first order approximation of suspension and tyre deformation effects to derive the actual load on each wheel. This leads to suspension internal equilibrium conditions which represent the missing equations for the solution of the lateral load transfer and the vertical load distribution. Even if sometimes the mathematical development is a bit involved the approach is rigorous and interesting since it is not always easy to find in such details in other books. The chapter closes with the introduction of a differential model that covers “any” differential type. The model is actually adopted in the analysis of vehicle handling characteristics or steering performance which is a subject of the following chapters.

Chapter 4 substantially deals with the braking balance concept both analytically and graphically adding the effect of aerodynamics. The analysis of traction is missing and it would be a possible improvement for future edition of the book.

Chapter 5 starts with the kinematics of a rigid body which is then applied to the case of a turning vehicle considered as a single planar rigid body. The chapter discusses concepts that are very often underestimated in vehicle dynamics such as centres of acceleration and of curvature. Most of books about vehicle dynamics treat the steady state turning, which is a sub-case of the more general transient motion. Therefore the instantaneous rotation centre can be assumed to be the centre of curvature which is actually not true for transient motion. The interpretation of the vehicle kinematics with the moving and fixed centroid is interesting and inspiring for further research but it still needs additional investigation from the author in order to give a more general indication of what “good” means for the steering behaviour of a vehicle.

Chapter 6, which is the one I like the most with chapter 3, treats the steering attitude of a road car according to the traditional approach of the handling diagram and introducing a new concept: the *map of achievable performance*. The chapter stemming from the equations of dynamics of chapter 3 derives two models: the double track model and the single track model. For the single track model, it discusses the axle characteristics, quite nicely, and the steady state conditions under different sets of coordinates (namely side slip  $\beta$ , curvature  $\rho$ , lateral acceleration  $a_y$ ). Here the understeer and oversteer characteristics are defined in term of *slip functions* and of *steering gradients*. However the most valuable part of the chapter is the map of achievable performance that provides a visually immediate representation of both vehicle steering behaviour and maximum performance both for linear and non linear conditions and under constant velocity, lateral acceleration or steering angles. The relationship between steady state data and transient behaviour is really made clear providing a new understeering gradient definition. The chapter closes with a revised vision of the single track model. In chapter 7 the above concepts are applied to racing vehicles.

Chapter 8 treats in a standard way the “Ride Comfort and Road Holding” topic but with two interesting highlights: the introduction of the *inertor* and its usefulness for racing vehicles and the discussion of optimal setup of suspensions from the point of view of road holding and comfort.

Chapter 9 extends the concept of handling including roll and eventually pitch motion. This is done deriving the equations of motion for a vehicle where the sprung mass has also the degrees of freedom that correspond to heave, roll and pitch. The model development stems from the definition of the *vehicle invariant point* as origin of the frame with respect to which the equations are expressed. This is an alternative option compared to the most common roll axis approach. The idea is quite interesting and new and establishes sound and consistent basis for vehicle dynamic models with constant track width, which are widely adopted in the scientific and engineering community. Additionally the derivation of the equations is neat and expressed into a condensed and clear form. Nevertheless the definition of the invariant point is not completely clear and needs further explanations from the author.

Chapter 10 develops the theoretical and mathematical equations of the brush model in a clear and rigorous way, which readers will hardly find in other textbooks.

Guiggiani's book is an excellent contribution to the comprehension of vehicle dynamics both for undergraduate students and experts in the field. It also has the merit to propose new concepts and interpretations (even if some are more convincing than others) despite 50 years of books on vehicle dynamics. A second value of the book is its rigorous approach, which does not leave nothing either to mere intuition or for granted. Nevertheless sometimes there is too much emphasis on highlighting overlook issues or concepts by scientific and automotive researchers and engineers. As a concluding remarks I think that a follow up of this book might further develop the new proposed concepts with more examples, and if possible, with experimental data.

#### Compliance with ethical standards

**Human and animal rights** The authors declare that the research does not involved human and animal participants.

**Conflict of interest** The authors declare that they have no conflict of interest.

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