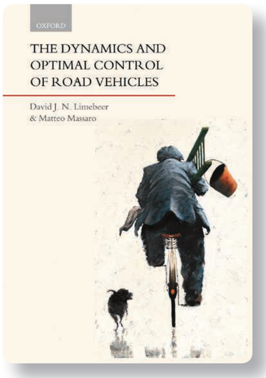
IEEE Control Systems welcomes suggestions for books to be reviewed in this column. Please contact either Scott R. Ploen, Hong Yue, or Thomas Schön, associate editors for book reviews.



Oxford University Press, 2018,
ISBN: 978-0198825715
480 Pages, US$90.00

THE DYNAMICS AND OPTIMAL CONTROL OF ROAD VEHICLES

by DAVID J.N. LIMEBEER and MATTEO MASSARO

Reviewed by Jacob P. Meijaard

This book applies fundamental results from classical mechanics, tire mechanics, vehicle modeling, and optimal control theory to various kinds of road vehicles, including cars, motorcycles, and bicycles. The combination of vehicle modeling, dynamics, and optimal control presented in a unified manner makes this book stand out from others in this subject area.

The assumed background of readers includes linear algebra, mechanics, linear systems, and classical control theory. Basic familiarity with the calculus of variations would also be helpful. The style is more formal than most other books on vehicle dynamics, such as [1]. Although most results are carefully stated and derived, mathematical formalism is kept to a minimum, making this book suitable for students in engineering and automotive industry practitioners.

CONTENTS

The book consists of nine chapters. Chapter 1 provides a short overview of the historical development of carriages, cars, bicycles, motorcycles, and tires.

Chapter 2 provides an extensive overview of classical mechanics. Some advanced topics are included, such as Hamilton's equations and nonholonomic systems. The student who encounters this material for the first time might have difficulty following the presentation. However, ample references are given to the literature. It should also be noted that some of the advanced results are not needed for understanding the rest of the book. This chapter ends with examples of nonholonomic systems, which set the stage for modeling tire–road contact.

Chapter 3 addresses the important topic of tire modeling. The tire model describes the generation of force components between the wheel and ground as functions of slip quantities that characterize the departure of the tire from pure rolling motion. The partial differential equations governing the deformations and slips at the contact patch of a rolling tire are then discussed. The generation of steady-state tire forces is covered next. Both the brush model and semiempirical "magic formula" model are covered. Transient/unsteady effects are discussed next, with emphasis on the pure string model. Modifications to the "magic formula" model to handle unsteady operating conditions are also given. Overall, the coverage of this material relies heavily on [2].

Chapter 4 is an introduction to vehicle modeling, which starts with the elementary vehicle model of [3] and its implications for steering, cornering behavior, and stability. This model is then extended for an accelerated or braked vehicle. Examples are provided, including a bicycle model with prescribed steering and a lumped three-mass bicycle model. The chapter ends with a discussion of wheel shimmy, the oscillatory motion of wheels predominantly about a vertical axis.

Chapter 5 presents the simplest bicycle model that can still realistically describe its dynamic behavior, the so-called Whipple model. The linearized equations of motion are derived as in [4], and their control-theoretical implications are then discussed. Model extensions, including frame flexibility and the influence of more realistic tire models, are also presented.

Chapter 6 covers the vertical dynamics of vehicles, with the goal of optimizing comfort, road holding, and suspension travel. Quarter-, half-, and full-car models are provided. The input motion due to the road unevenness is characterized as a random process. The invariant characteristics of the transfer functions are displayed, and a cost function is optimized via a covariance analysis. Examples are also provided that illustrate the theory.

Chapter 7 treats some advanced topics, including trim and load transfer during acceleration, braking and cornering, heave and pitch behavior, road modeling, and the kinematics of suspensions and steering systems. Cars and motorcycles are both considered. For more complex vehicle models, use is made of multibody system dynamics software to automatically generate the equations of motion.

The last two chapters address optimal control. Pontryagin's maximum principle, presented as an equivalent minimum

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principle, and dynamic programming are emphasized. The concepts of bang–bang control and singular arcs are applied to the optimal braking of a wheel. Attention is also paid to numerical methods for solving optimal control problems. The theory is then applied to some vehicle dynamics problems, including the minimal energy consumption of a car traveling on an inclined road and a comprehensive example of a Formula One racing car subject to constraints on the vehicle dynamics and powertrain.

SUMMARY

The content of the book reflects the personal interests of the authors and summarizes much of their previously published research. The emphasis is more on dynamics and modeling and less on control theory. The point the authors are trying to make seems to be that, to apply optimal control effectively, a good model of the dynamics of the system is first needed. Readers working with control applications could be a little disappointed that more topics on road vehicle control are not included.

A few minor errors in some of the equations are present, most of which can be easily spotted by readers. In some places, the prose is not as clear as it could be. However, the overall presentation is solid, and the shortcomings are few. The list of more than 400 references provides a good starting point for those who wish to delve deeper into the subject. However, the bibliography still has a few notable omissions, such as [3]. In summary, the book is a valuable resource for students and researchers in the area of the dynamics and control of road vehicles. The book contains a wealth of material. This reviewer personally learned several things from it.

REVIEWER INFORMATION

Jacob P. Meijaard (j.p.meijaard@utwente.nl) received the M.Sc. degree in mechanical engineering and the Ph.D. degree from Delft University of Technology. He is a researcher at the University of Twente, Enschede, 7522, The Netherlands, and at Delft University of Technology, Delft, 2628, The Netherlands. His research interests include all aspects of dynamics but especially vehicle dynamics and the dynamics of mechanisms.

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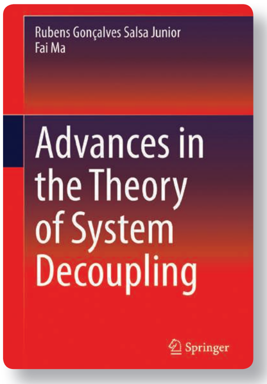
[1] G. Genta, *Motor Vehicle Dynamics, Modeling and Simulation*. Singapore: World Scientific, 2006.

[2] H. B. Pacejka and I. Besselink, *Tire and Vehicle Dynamics*, 3rd ed. Oxford: Butterworth-Heinemann, 2012.

[3] P. Riekert and T. E. Schunk, “Zur Fahrmechanik des gummibereiften Kraftfahrzeugs,” *Ingenieur-Archiv*, vol. 11, no. 3, pp. 210–224, 1940. doi: 10.1007/BF02086921.

[4] J. P. Meijaard, J. M. Papadopoulos, A. Ruina, and A. L. Schwab, “Linearized dynamics equations for the balance and steer of a bicycle: A benchmark and review,” *Proc. Roy. Soc. A*, vol. 463, no. 2084, pp. 1955–1982, 2007. doi: 10.1098/rspa.2007.1857.

Book Announcements

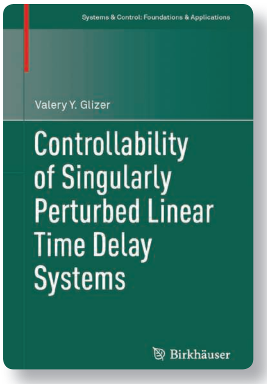


Springer, 2021,
ISBN: 978-3-030-60845-3,
178 pages, US$149.99.

Advances in the Theory of System Decoupling

by R.G. SALSA JR. and F. MA

This book presents a concise and consistent account of the methodology of phase synchronization, an extension of modal analysis to decouple any linear system in real space. It expounds on the theory of phase synchronization while also providing relevant background on classical decoupling theories that are used in structural analysis. The theory is illustrated with a range of examples and also supplemented by applications to engineering problems. In addition, the methodology is implemented via Matlab algorithms, which can be used to solve many of the examples given in the book. This text is suited for researchers, practicing engineers, and graduate students in various fields of engineering, mathematics, and the physical sciences.



Birkhauser, 2021,
ISBN: 978-3-030-65950-9,
431 pages, US$139.99.

Controllability of Singularly Perturbed Linear Time Delay Systems

by V.Y. GLIZER

After a brief overview of the field, this book examines the properties of different classes of singularly perturbed time-delay systems, including linear time-dependent systems with multiple pointwise and distributed state delays. Euclidean space controllability is also discussed, and numerous examples are provided to illustrate the theoretical results. More technically complicated proofs are presented in separate subsections. The final chapter includes a section dedicated to nonlinear time-delay systems. This book should be of interest to researchers, engineers, and graduate students in systems science and control theory. Applied mathematicians and researchers working in the biological sciences may also find this volume to be a useful resource.

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