INTERNATIONAL JOURNAL OF ROBUST AND NONLINEAR CONTROL
Int. J. Robust Nonlinear Control 2006; **16**:547–551
Published online in Wiley InterScience (www.interscience.wiley.com)

BOOK REVIEWS

GEOMETRIC CONTROL OF MECHANICAL SYSTEMS: MODELLING, ANALYSIS, AND DESIGN FOR SIMPLE MECHANICAL CONTROL SYSTEMS, Francesco Bullo and Andrew D. Lewis, Springer, New York, NY, 2005

Building on the rich history of mechanics and control, the book by Bullo and Lewis provides a unifying and contemporary view on the interesting subject of geometric control theory for mechanical systems. The elegant language of Riemannian geometry leads the authors to a self-contained treatment of many subjects at the intersection of Lagrangian mechanics and control theory. The book's focus is squarely on the mathematical modelling, analysis, and control of what the authors name 'simple' mechanical systems, which are systems whose total energy is the sum of kinetic and potential energy. The book represents a major effort in presenting a rigorous, complete and accurate combined theory of geometric control of mechanical systems.

The book is written with the intent of being a textbook. The preliminary chapters review the required background. Plenty of examples and exercises are provided throughout the manuscript; a collection of example mechanical control systems accompanies the reader throughout the book; an incomplete list includes rigid bodies in two and three dimensions, pendula of various kind, planar manipulators, and nonholonomic systems such as the rolling disk, the roller racer and the snakeboard. Additionally, very good care is taken in the mathematical precision and exposition of results; this latter feature is clearly a plus for the manuscript. However, this attention to detail does, here and there, render some topics difficult to digest for people with an engineering background interested in understanding the main line and not the technicalities.

The book has many hallmarks of a well written careful work. The writing style is accurate and uniform. The formatting is elegant and consistent throughout the book. The subject and symbol indexes are compiled very carefully. The references are very accurate and very consistent; they include a careful historical research work on the origins of many of today's classics (even though the authors neglect to mention the original papers by W. R. Hamilton; this absence is acknowledged in the errata). Finally, the authors also maintain a detailed and updated web companion to the book at (http://penelope.mast.queensu.ca/smcs/). This informative web site contains some supplementary chapters to the book, an up to date errata, some mathematica packages related to the book, and some summary slides on the book material, to name a few.

In a very scholarly fashion, the book is organized in three parts: modelling, analysis and design. The Modelling Part describes the unifying differential and Riemannian geometry language that permeates the entire book. The fundamental material exposed in the book is in Chapters 3 and 4 on 'Differential Geometry' and on 'Simple mechanical Control Systems.' These subjects are presented in a self-contained and rigorous manner; these two chapters alone provide plenty of notions, examples and challenges for initiated and expert readers alike. The key object is obtained by regarding the inertia tensor of a mechanism as a Riemannian metric on the manifold representing the configuration of the mechanism. Such a Riemannian structure allows one to define a related 'affine connection', which is then used in the analysis of the system under study in a very constructive way. Furthermore, this affine connection is nicely adapted to take into consideration nonholonomic constraints; this is shown in Chapter 4. The first part of the book then concludes with a nice treatment of mechanical control systems whose configuration space is a Lie group or whose Lagrangian has symmetries.

The second part of the book is devoted to analysis problems for mechanical control systems, including stability, controllability, averaging, and kinematic reductions. The chapters in this and in the next part are organized as follows: first, a general review of notions relevant for nonlinear dynamical or control systems is given, and then the special case of simple mechanical control systems is treated. These reviews are, on their own, a self-contained review of aspects of geometric control theory. This second part also contains the interesting concept of kinematic reduction, which gives a precise formulation of when, roughly speaking, a mechanical control system can be characterized by studying appropriate driftless first-order systems, called kinematic reductions.

The third part of the book is devoted to a collection of control design problems, including potential shaping for fully actuated and under-actuated systems, tracking using oscillatory controls, and motion planning using kinematic reductions. As explained by the authors, this part is to be understood as a collection of approaches, rather than the comprehensive fully developed treatment in the modelling and analysis parts. Chapter 10 and 11 contain a nice review of potential shaping methods; here this is limited to potential energy shaping. Chapter 12 contains control laws based on the averaging techniques previously introduced. Finally, Chapter 13 contains motion planning algorithms for mechanical control systems that admit controllable kinematic reductions.

On numerous counts, this text is a unique textbook-style reference for subjects rarely exposed in the literature. Examples include the treatment of detailed distributions in Chapter 3, aspects of the physical modelling in Chapter 4, and the controllability theory in Chapter 7. Without any doubt this book will become a classic in the field and, due to its completeness, it will very likely be considered as the 'bible' in this specific methodology for the study of mechanical systems using Riemannian Geometry.

Related nice volumes are the book of Bloch [1] and the book of Nijmijer and van der Schaft [2], just to name a few [3, 4]. I dare to say that the work is a real masterpiece, and the only critique which I may express is the fact that its extreme preciseness of exposition may prevent a broader public to appreciate the beauty of the methodologies presented in this volume.

REFERENCES

1. Bloch AM. *Nonholonomic Mechanics and Control*. Springer: New York, NY, 2003.
2. Nijmeijer H, van der Schaft A. *Nonlinear Dynamical Control Systems*. Springer: New York, NY, 1990.
3. Abraham R, Marsden JE. *Foundations of Mechanics*. Addison-Wesley: New York, NY, 1994.
4. Arnold VI. *Mathematical Methods of Classical Mechanics*. Springer: New York, NY, 1989.

STEFANO STRAMIGIOLI
Control Engineering Laboratory,
IMPACT Institute,
University of Twente,
P.O. Box 217, NL-7500 AE Enschede,
The Netherlands
E-mail: s.stramigioli@ieee.org

(DOI: 10.1002/rnc.1064)

SOFT COMPUTING AND INTELLIGENT SYSTEMS DESIGN: THEORY, TOOLS AND APPLICATIONS, F. O. Karry and C. De Silva, Pearson, Addison-Wesley, New York, NY, 2004

1. INTRODUCTION

Intelligence is defined, according to Webster's Dictionary, as 'the capacity to apprehend facts and propositions and their relations and to reason about them'. In terms of hierarchy, the intelligence occupies next to genius 'person with very high intelligent quotient' as shown in Figure 1. At the bottom of the ladder is the *data* which when formatted becomes *information* to be useful for any analysis. If one acquires a lot of information, he/she becomes a knowledgeable person. If *knowledge* is used with respect to facts and reason, it becomes *intelligence*. A highly intelligent person becomes a *genius*. The conventional *artificial intelligence* (AI) refers to mimicking human

