

Preface

An underactuated mechanical system (UMS) is a system that has fewer control inputs than degrees of freedom. In contrast, a fully actuated mechanical system is one that has the same number of actuators as degrees of freedom. Underactuated mechanical systems arise in many real-life applications such as aircrafts, helicopters, spacecrafts, vertical take-off and landing aircrafts, underwater vehicles, mobile robots, walking robots, just to mention a few. Unlike fully actuated mechanical systems, the control of UMSs is quite a challenging task because the latter present a restriction on the control authority that makes the control design for these systems rather complicated. Also, very often it gives rise to complex theoretical problems that are not found in fully actuated systems and that cannot be solved using classical control techniques. In effect, some established results and properties of nonlinear systems such as feedback linearizability and passivity are no longer valid in the case of UMSs. Other undesirable properties like possessing an undetermined relative degree or being in a non-minimum phase are also customarily present in these systems. Moreover, several of these systems present a structural obstruction to the existence of smooth time invariant stabilizing control laws. Also, it is generally not easy to determine the controllability, at least locally, for these systems and even when they are controllable, the control laws can be discontinuous, periodic, and variant in time.

The control of UMSs has been investigated for quite a long time in the control literature and has been attracting more attention in recent years because of the growing interests in new robotic applications such as unmanned underactuated aerial or underwater vehicles. Different control strategies have been proposed in the literature, including backstepping, sliding mode, intelligent control, and much more. Several authors have attempted to present a classification and a generalization of these systems with the aim of proposing a systematic control design method for UMSs. Despite the diversity and large amount of research on the topic, it is difficult to highlight the structural properties of UMSs in a sufficiently general and exploitable manner that allows an unified treatment for the latter. As a matter of fact, there is no general theory that allows to conduct a systematic analysis and synthesis of control design

for all UMSs. This has been the main motivating factor for us to write this current monograph.

The book presents theoretical explorations on the fundamental classification methods that are available in the literature; namely, the control flow diagram (CFD)-based classification of Seto and Baillieul and the structural properties-based classification of Olfati-Saber. It also proposes some tools for the systematic control design for underactuated systems. It aims to present a reference material for researchers and students working in the field of underactuated mechanical control. As such, the book is primarily intended for researchers and engineers in the system and control community. It can also serve as a complementary reading for post-graduated students studying control system theory.

Tlemcen, Algeria
August 2013

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Analysis and Control of Underactuated Mechanical
Systems

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2014, XV, 138 p. 55 illus., 10 illus. in color., Hardcover

ISBN: 978-3-319-02635-0