

Preface

The purpose of this book is to provide a detailed presentation of a novel block backstepping based control law that can address the control problems of a large class of underactuated mechanical systems in a generalized manner. Study of control problems of the underactuated systems and thereafter devising appropriate control actuations for those are presently being pursued with utmost vigor by the control research groups. The reason behind this is the appeal of the dynamic nature of the systems along with the challenges they pose. Such systems belong to a class that has a wide spectrum in reality not even restricting their domains related to Robotics, Aerospace, Industrial Processes, Marine systems etc. Consequently, a lot of theoretical propositions as well as practical application oriented approaches have been reported in the literature during the last few decades. Undoubtedly, those research contributions have enriched the literature of control engineering to a great extent, but quite often they fail to compromise between the theory and practice. Theoretical approaches can ensure global asymptotic stability during analysis, while their complicated mathematical formulations restrict their implementations on the practical systems in real-time. On the other hand, application-oriented approaches are absolutely system specific, and eventually they fail to answer the control problems of the other systems of similar nature. Therefore, design of a generalized control law based on block backstepping has been presented in this book in a structured manner.

The theory and further employment of Block backstepping based control law has been developed in a versatile manner, so that the control action generated, thereby, can ensure global asymptotic stability for most of the underactuated mechanical systems and at the same time can guarantee a desired performance during real-time implementations.

Indeed complicated state model of underactuated mechanical system restricts the straightforward applications of naïve integrator backstepping method. Therefore, the authors of this book have endeavored to establish an algebraic transformation

that could be used to reconfigure the original system model into a reduced order block-strict-feedback form. To be more precise, through this generic matrix-algebraic transformation, a higher order nonlinear underactuated system can be transfigured as a system having two cascaded blocks; the reduced order system modelled and depicted in strict feedback form followed by a dynamic block that actually represents the unobservable internal dynamics of the transformed system. Thereafter, integrator backstepping has been explored to devise a control law for the reduced order system as well as to assess and ensure the stability of internal dynamics of the entire system. Further, applications of the so devised control law on ten different systems (having completely different system dynamics) have been demonstrated in the simulation and real-time environment to corroborate the theoretical findings.

We reiterate that this book is intended to be used as a reference book by the graduate students and incumbent researchers in the areas of nonlinear control systems, mechanical systems, mechatronics, and robotics.

The book originates from the doctoral thesis prepared by the first author at the Jadavpur University of India and supervised by the second and third authors. Chapter 2 has been incorporated to provide with the prerequisite knowledge of nonlinear control theory that might be helpful to the new yet potential researchers in this domain. Thereafter, Chap. 3 has systematically presented the derivation of Block backstepping control law. At the onset, stepwise formulation of the control law has been described for the 2-DOF underactuated mechanical systems. After that, a generalized version of the control law has been presented to address the control problems of n -DOF underactuated mechanical systems. Chapter 4 has been devoted to demonstrate the applications of the control law on seven different underactuated systems, namely, inertia wheel pendulum, TORA, Furuta pendulum, acrobot, pendubot, inverted pendulum, and single dimensional Granty crane. For the first five systems, mentioned above, performances of the control law have been evaluated in the Matlab[®] Simulation environment. Moreover, the block backstepping control law has been employed for the inverted pendulum and overhead crane in real-time environment in a benchmark laboratory environment. For both the cases, it has been observed that the experimental outcomes have nearly corroborated with the theoretical findings. In Chap. 5, applications of the control law on higher-order systems have been portrayed, and have been substantiated with detailed simulation results. The authors hope that this reference book would be able to impart subtle yet sufficient knowledge about mathematical and implementation-oriented nuances towards control of under actuated nonlinear systems. The experiences gained by the authors while pursuing the work, are being conveyed to the research community of the future through this book.

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