Research Article

Robust Tracking Control of Robot Manipulators Using Only Joint Position Measurements

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This paper concerns the tracking control of a robot manipulator with unknown uncertainties and disturbances. It presents a new control method that uses only joint position measurements to design a tracking controller. The controller has two parts. One is based on a feedback linearization technique; it makes the nominal model of a manipulator asymptotically track a desired trajectory. The other is based on the idea of equivalent input disturbance (EID); it compensates for uncertainties and disturbances. Together they enable a robot manipulator to precisely track the desired trajectory. The new control algorithm is applied to a two-link robot manipulator, and simulation results demonstrate the validity of this method.

1. Introduction

Robot manipulators are widely used in many fields. They are especially useful in areas where it is impractical or undesirable for a human to go, for example, undersea exploration, radioactive environments, and defusing explosive devices. Interest in the control of robot manipulators has been increasing over the past few years [1–3], and it is now a central issue in robotics.

If an exact dynamic model of a robot manipulator is known, the motion control problem is easy to solve by the computed-torque-control (CTC) method [4]. It uses nonlinear state feedback to cancel the nonlinear terms and a simple PD controller for motion control. Although this method is simple and effective, the requirement of an exact model limits its practicality because it is usually impossible to obtain an exact, or even reasonably accurate, dynamic model in practical applications. For example, an actual plant inevitably contains structured and unstructured uncertainties, and a robot manipulator may be influenced by unpredictable external disturbances when the operating environment changes. Since these uncertainties and disturbances may greatly affect

control performance, it is necessary to consider their effects in the study of the motion control of robot manipulators.

A number of strategies have been developed to solve the problem of controlling the motion of a robot manipulator with uncertainties and disturbances. They include a Lyapunov-based method [5], a neural-network-based method [6, 7], an adaptive neural network H_∞ strategy [8], an adaptive switching learning PD (ASL-PD) method [9], a parameter-dependent nonlinear observer approach [10], and a variable-structure PID control method [11]. However, all of them require measurement of both the displacement and velocity of joints.

Generally speaking, joint displacement can be accurately measured with an encoder. However, velocity is typically measured with a tachometer, and the results usually contain noise, which can affect the control precision and performance of a closed-loop system. So, both practically and theoretically, it is meaningful to devise a motion control method for robot manipulators which relies only on the measurement of joint position. Various strategies have been developed to solve this challenging problem. One is a controller-observer combination strategy. It has a two-step design procedure:

Robust Tracking Control Of Robot Manipulators

Dan Zhang,Bin Wei

Robust Tracking Control Of Robot Manipulators:

  Robust Tracking Control of Robot Manipulators Zhihua Qu,D. M. Dawson,1996 Bringing together the latest research in the field Robust Tracking Control of Robot Manipulators is the first book to provide systematic methods for stabilizing unwanted flexible uncertain and unmodeled dynamics The authors present a thorough comparison of state of the art and classical designs of all controls linear or nonlinear simple or complicated conventional or robust adaptive or learning Focusing on control design and performance analysis this book will help you to apply advanced controls effectively and to establish equivalent and different robustness This book will be invaluable as a guide to researchers and practicing engineers in the field of robot control automation and robotic engineering It will also serve as a useful reference for control of robot manipulators and mechanical electrical systems   **Perturbation Compensator based Robust Tracking Control and State Estimation of Mechanical Systems** SangJoo Kwon,Wan Kyun Chung,2004-07-07 This monograph investigates a practical way to achieve robust motion control and state estimation Kalman filtering of mechanical systems which is a promising approach in terms of the perturbation compensator The book presents novel approaches for design and analysis of perturbation observers as well as an extension to robust motion control and robust state estimation The book is written in a self contained manner including experimental results in each chapter clearly validating the developed theories   Modelling and Control of Robot Manipulators Lorenzo Sciavicco,Bruno Siciliano,2001-02-19 Fundamental and technological topics are blended uniquely and developed clearly in nine chapters with a gradually increasing level of complexity A wide variety of relevant problems is raised throughout and the proper tools to find engineering oriented solutions are introduced and explained step by step Fundamental coverage includes Kinematics Statics and dynamics of manipulators Trajectory planning and motion control in free space Technological aspects include Actuators Sensors Hardware software control architectures Industrial robot control algorithms Furthermore established research results involving description of end effector orientation closed kinematic chains kinematic redundancy and singularities dynamic parameter identification robust and adaptive control and force motion control are provided To provide readers with a homogeneous background three appendices are included on Linear algebra Rigid body mechanics Feedback control To acquire practical skill more than 50 examples and case studies are carefully worked out and interwoven through the text with frequent resort to simulation In addition more than 80 end of chapter exercises are proposed and the book is accompanied by a solutions manual containing the MATLAB code for computer problems this is available from the publisher free of charge to those adopting this work as a textbook for courses   Robot Control 1991 (SYROCO'91) I. Troch,2014-05-23 This volume contains 92 papers on the state of the art in robotics research In this volume topics on modelling and identification are treated first as they build the basis for practically all control aspects Then the most basic control tasks are discussed i e problems of inverse kinematics Groups of papers follow which deal with various advanced control aspects They range from rather general methods to more specialized topics such as

force control and control of hydraulic robots The problem of path planning is addressed and strategies for robots with one arm for mobile robots and for multiple arm robots are presented Also covered are computational improvements and software tools for simulation and control the integration of sensors and sensor signals in robot control **Springer Handbook of Robotics** Bruno Siciliano,Oussama Khatib,2016-07-27 The second edition of this handbook provides a state of the art overview on the various aspects in the rapidly developing field of robotics Reaching for the human frontier robotics is vigorously engaged in the growing challenges of new emerging domains Interacting exploring and working with humans the new generation of robots will increasingly touch people and their lives The credible prospect of practical robots among humans is the result of the scientific endeavour of a half a century of robotic developments that established robotics as a modern scientific discipline The ongoing vibrant expansion and strong growth of the field during the last decade has fueled this second edition of the Springer Handbook of Robotics The first edition of the handbook soon became a landmark in robotics publishing and won the American Association of Publishers PROSE Award for Excellence in Physical Sciences Mathematics as well as the organization s Award for Engineering Technology The second edition of the handbook edited by two internationally renowned scientists with the support of an outstanding team of seven part editors and more than 200 authors continues to be an authoritative reference for robotics researchers newcomers to the field and scholars from related disciplines The contents have been restructured to achieve four main objectives the enlargement of foundational topics for robotics the enlightenment of design of various types of robotic systems the extension of the treatment on robots moving in the environment and the enrichment of advanced robotics applications Further to an extensive update fifteen new chapters have been introduced on emerging topics and a new generation of authors have joined the handbook s team A novel addition to the second edition is a comprehensive collection of multimedia references to more than 700 videos which bring valuable insight into the contents The videos can be viewed directly augmented into the text with a smartphone or tablet using a unique and specially designed app Springer Handbook of Robotics Multimedia Extension Portal http handbookofrobotics org

Virtual Decomposition Control Wen-Hong Zhu,2010-04-06 Driven by the need to achieve superior control performances for robots with hyper degrees of freedom the virtual decomposition control approach is thoroughly presented in this book This approach uses subsystem such as links and joints of a complex robot dynamics to conduct control design while guaranteeing the stability and convergence of the entire complex robot without compromising the rigorousness of the system analysis The central concept of this approach is the definition of the virtual stability The stability of the entire complex robot is mathematically equivalent to the virtual stability of every subsystem This fact allows us to convert a large problem to a few simple problems with mathematical certainty This book comprises fourteen chapters The first five chapters form the foundation of this approach The remaining nine chapters are relatively independent Starting from Chapter 6 each chapter deals with a particular type of systems including motor transmission assemblies hydraulic robots coordinated multiple robots

space robots humanoid robots adaptive teleoperation and modular robot manipulators At the end the extensions of this approach to distributed parameter systems and to electrical circuits are given paving the way for other applications to follow This book is intended for practitioners researchers and graduate students who have acquired fundamental knowledge on robotics and control systems and have been committed to achieving the best control performances on complex robotics systems and beyond **PID Trajectory Tracking Control for Mechanical Systems** Youngjin Choi,Wan Kyun Chung,2004-01-23 Though PID control has a long history as much as its life force since Ziegler and Nichols published the empirical tuning rules in 1942 surprisingly it has never been changed in the structure itself The strength of PID control lies in the simplicity lucid meaning and clear e ect Though it must be a widely cepted controller for mechanical control systems it is still short of theoretical bases e g optimality performance tuning rules automatic performance t ing method and output feedback PID control have not been clearly presented formechanicalcontrolsystems Thesesubjectswillbethoroughlydiscussedin this book There are many books of PID controller for the purpose of process control but it is hard to nd a book on the characteristics of PID control for mechanical systems In the rst place when nonlinear optimal control theory is applied to mechanical systems a class of Hamilton Jacobi HJ equations is derived as a result of optimization There are two methods to solve a class of HJ eq tions a direct method using an approximation and inverse method nding the performance index from a class of HJ equations Also there are two control methods according to the objective the set point regulation control and t jectory tracking control The trajectory tracking control is basically di erent from set point regulation one in that the desired con guration velocity and acceleration pro les according to time progress are added to the motion of mechanical system This book is focusing on an inverse optimization method and the trajectory tracking control system *Control of Robot Manipulators in Joint Space* Rafael Kelly,Victor Santibáñez Davila,Julio Antonio Loría Perez,2007-12-14 Tutors can design entry level courses in robotics with a strong orientation to the fundamental discipline of manipulator control pdf solutions manual Overheads will save a great deal of time with class preparation and will give students a low effort basis for more detailed class notes Courses for senior undergraduates can be designed around Parts I III these can be augmented for masters courses using Part IV **Control and Dynamic Systems V50: Robust Control System Techniques and Applications** C.T. Leonides,2012-12-02 Control and Dynamic Systems Advances in Theory and Applications Volume 50 Robust Control System Techniques and Applications Part 1 of 2 is a two volume sequence devoted to the issues and application of robust control systems techniques This volume is composed of 10 chapters and begins with a presentation of the important techniques for dealing with conflicting design objectives in control systems The subsequent chapters describe the robustness techniques of systems using differential difference equations the design of a wide class of robust nonlinear systems the techniques for dealing with the problems resulting from the use of observers in robust systems design and the effective techniques for the robust control on non linear time varying of tracking

control systems with uncertainties These topics are followed by discussions of the effective techniques for the robust control on non linear time varying of tracking control systems with uncertainties and for incorporating adaptive control techniques into a non adaptive robust control design Other chapters present techniques for achieving exponential and robust stability for a rather general class of nonlinear systems techniques in modeling uncertain dynamics for robust control systems design and techniques for the optimal synthesis of these systems The last chapters provide a generalized eigenproblem solution for both singular and nonsingular system cases These chapters also look into the stability robustness design for discrete time systems This book will be of value to process and systems engineers designers and researchers   Robotics 2010 Houssem Abdellatif,2010-02-01 Without a doubt robotics has made an incredible progress over the last decades The vision of developing designing and creating technical systems that help humans to achieve hard and complex tasks has intelligently led to an incredible variety of solutions There are barely technical fields that could exhibit more interdisciplinary interconnections like robotics This fact is generated by highly complex challenges imposed by robotic systems especially the requirement on intelligent and autonomous operation This book tries to give an insight into the evolutionary process that takes place in robotics It provides articles covering a wide range of this exciting area The progress of technical challenges and concepts may illuminate the relationship between developments that seem to be completely different at first sight The robotics remains an exciting scientific and engineering field The community looks optimistically ahead and also looks forward for the future challenges and new development   *Adaptive Control for Robotic Manipulators* Dan Zhang,Bin Wei,2017-02-03 The robotic mechanism and its controller make a complete system As the robotic mechanism is reconfigured the control system has to be adapted accordingly The need for the reconfiguration usually arises from the changing functional requirements This book will focus on the adaptive control of robotic manipulators to address the changed conditions The aim of the book is to summarise and introduce the state of the art technologies in the field of adaptive control of robotic manipulators in order to improve the methodologies on the adaptive control of robotic manipulators Advances made in the past decades are described in the book including adaptive control theories and design and application of adaptive control to robotic manipulators   **Adaptive Control of Robot Manipulators** An-Chyau Huang,Ming-Chih Chien,2010 This book introduces an unified function approximation approach to the control of uncertain robot manipulators containing general uncertainties It works for free space tracking control as well as compliant motion control It is applicable to the rigid robot and the flexible joint robot Even with actuator dynamics the unified approach is still feasible All these features make the book stand out from other existing publications   **Trackability and Tracking of General Linear Systems** Lyubomir T. Gruyitch,2018-10-31 Trackability and Tracking of General Linear Systems deals with five classes of the systems three of which are new begins with the definition of time together with a brief description of its crucial properties and with the principles of the physical uniqueness and continuity of physical variables They are essential for the natural

tracking control synthesis The book presents further new results on the new compact simple and elegant calculus that enabled the generalization of the transfer function matrix concept and of the state concept the completion of the trackability and tracking concepts together with the proofs of the trackability and tracking criteria as well as the natural tracking control synthesis for all five classes of the systems Features Crucially broadens the state space concept and the complex domain fundamentals of the dynamical systems to the control systems Addresses the knowledge and ability necessary to study and design control systems that will satisfy the fundamental control goal Outlines new effective mathematical means for effective complete analysis and synthesis of the control systems Upgrades completes and essentially generalizes the control theory beyond the existing boundaries Provides information necessary to create and teach advanced inherently upgraded control courses   Soft Computing: Theories and Applications Millie Pant,Kanad Ray,Tarun K. Sharma,Sanyog Rawat,Anirban Bandyopadhyay,2017-11-23 This book focuses on soft computing and its applications to solve real life problems occurring in different domains ranging from medical and health care supply chain management and image processing to cryptanalysis It presents the proceedings of International Conference on Soft Computing Theories and Applications SoCTA 2016 offering significant insights into soft computing for teachers and researchers and inspiring more and more researchers to work in the field of soft computing The term soft computing represents an umbrella term for computational techniques like fuzzy logic neural networks and nature inspired algorithms In the past few decades there has been an exponential rise in the application of soft computing techniques for solving complex and intricate problems arising in different spheres of life The versatility of these techniques has made them a favorite among scientists and researchers working in diverse areas SoCTA is the first international conference being organized at Amity University Rajasthan AUR Jaipur The objective of SoCTA 2016 is to provide a common platform to researchers academicians scientists and industrialists working in the area of soft computing to share and exchange their views and ideas on the theory and application of soft computing techniques in multi disciplinary areas The aim of the conference is to bring together young and experienced researchers academicians scientists and industrialists for the exchange of knowledge SoCTA especially encourages the young researchers at the beginning of their career to participate in this conference and present their work on this platform   **Robot Analysis and Control** H. Asada,J.-J. E. Slotine,1991-01-16 Introduces the basic concepts of robot manipulation the fundamental kinematic and dynamic analysis of manipulator arms and the key techniques for trajectory control and compliant motion control Material is supported with abundant examples adapted from successful industrial practice or advanced research topics Includes carefully devised conceptual diagrams discussion of current research topics with references to the latest publications and end of book problem sets Appendixes Bibliography   Proceedings of International Conference on Image, Vision and Intelligent Systems 2023 (ICIVIS 2023) Peng You,Shuaiqi Liu,Jun Wang,2024-02-24 This book constitutes the refereed proceedings of ICIVIS2023 held in Baoding China in August 2023 The papers included in the proceedings have been carefully

reviewed and selected from the submitted manuscripts in the areas of image vision and intelligent systems This book provides a reference for theoretical innovative problems as well as recent practical solutions and applications for the state of the art results in image vision and intelligent systems The intended audience of the book includes researchers professors experts practitioners and professionals in the field of image vision and intelligent systems worldwide **Field and Service Robotics** Alexander Zelinsky,2012-12-06 Joe Engelberger the pioneer of the robotics industry wrote in his 1989 book Robotics in Service that the inspiration to write his book came as a reaction to an industry sponsored forecast study of robot applications which predicted that in 1995 applications of robotics outside factories the traditional domain of industrial robots would amount to less than 1% of total sales Engelberger believed that this forecast was very wrong and instead predicted that the non industrial class of robot applications would become the largest class Engelbergers prediction has yet to come to pass However he did correctly foresee the growth in non traditional applications of robots Robots are now beginning to march from the factories and into field and service applications This book presents a selection of papers from the first major international conference dedicated to field and service applications of robotics This selection includes papers from the leading research laboratories in the world together with papers from companies that are building and selling new and innovative robotic technology It describes interesting aspects of robots in the field ranging from mining agriculture construction cargo handling subsea operations removal of landmines to terrestrial exploration It also covers a diverse range of service applications such as cleaning propagating plants and aiding the elderly and handicapped and gives considerable attention to the technology required to realise robust reliable and safe robots *Proceedings of the International Conference on Advanced Mechanical Engineering, Automation, and Sustainable Development 2021 (AMAS2021)* Banh Tien Long,Hyung Sun Kim,Kozo Ishizaki,Nguyen Duc Toan,Ivan A. Parinov,Yun-Hea Kim,2022-05-03 This book presents selected peer reviewed proceedings of the International Conference on Advanced Mechanical Engineering Automation and Sustainable Development 2021 AMAS2021 held in the city of Ha Long Vietnam from November 4 to 7 2021 AMAS2021 is a special meeting of the International Conference on Material Machines and Methods for Sustainable Development MMMS with a strong focus on automation and fostering an overall approach to assist policy makers industries and researchers at various levels to position local technological development toward sustainable development The contributions published in this book stem from a wide spectrum of research ranging from micro and nanomaterial design and processing to special applications in mechanical technology environmental protection green development and climate change mitigation A large group of contributions selected for these proceedings also focus on modeling and manufacturing of ecomaterials **Advanced Intelligent Computing Theories and Applications - With Aspects of Theoretical and Methodological Issues** De-Shuang Huang,Laurent Heutte,Marco Loog,2007-07-31 This volume in conjunction with the two volumes CICS 0002 and LNAI 4682 constitutes the refereed proceedings of the Third International Conference on Intelligent Computing

held in Qingdao China in August 2007 The 139 full papers published here were carefully reviewed and selected from among 2 875 submissions Collectively these papers represent some of the most important findings and insights into the field of intelligent computing   Advances In Variable Structure Systems: Analysis, Integration And Application - Proceedings Of The 6th Ieee International Workshop On Variable Structure Systems Jian-xin Xu,Xing Huo Yu,2000-11-14 The last of such a workshop in the 20th Century this workshop aims not only to summarize the state of the art developments in VSS theory and applications but also identify new promising directions perceived as being important for VSS in the 21st century The 20th Century has witnessed the formation and consolidation of VSS theory and its applications It has also witnessed an emerging trend of cross fertilization and integration of VSS with other control and non control areas such as feedback linearization flatness passivity based control adaptive control system identification pulse width modulation Hinf geometric and algebraic methods artificial intelligence modelling and optimisation neural networks fuzzy logic etc This trend will continue and flourish in the new millennium Special features of the book include a survey paper entitled VSS Premise of XX Century Evidences of a Witness by the father of VSS theory Professor Vadim Utkin and other articles by many authoritative experts in VSS

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