

Iterative Learning Control

Analysis, Design, Integration
and Applications

Editors
Zeungnam Bien and Jian-Xin Xu

Iterative Learning Control Analysis Design Integration Applications

**Kok Kiong Tan, Tong Heng Lee, Sunan
Huang**



Iterative Learning Control Analysis Design Integration Applications:

Iterative Learning Control Zeungnam Bien, Jian-Xin Xu, 2012-12-06 Iterative Learning Control ILC differs from most existing control methods in the sense that it exploits every possibility to incorporate past control information such as tracking errors and control input signals into the construction of the present control action There are two phases in Iterative Learning Control first the long term memory components are used to store past control information then the stored control information is fused in a certain manner so as to ensure that the system meets control specifications such as convergence robustness etc It is worth pointing out that those control specifications may not be easily satisfied by other control methods as they require more prior knowledge of the process in the stage of the controller design ILC requires much less information of the system variations to yield the desired dynamic behaviors Due to its simplicity and effectiveness ILC has received considerable attention and applications in many areas for the past one and half decades Most contributions have been focused on developing new ILC algorithms with property analysis Since 1992 the research in ILC has progressed by leaps and bounds On one hand substantial work has been conducted and reported in the core area of developing and analyzing new ILC algorithms On the other hand researchers have realized that integration of ILC with other control techniques may give rise to better controllers that exhibit desired performance which is impossible by any individual approach

Iterative Learning Control David H. Owens, 2015-10-31 This book develops a coherent and quite general theoretical approach to algorithm design for iterative learning control based on the use of operator representations and quadratic optimization concepts including the related ideas of inverse model control and gradient based design Using detailed examples taken from linear discrete and continuous time systems the author gives the reader access to theories based on either signal or parameter optimization Although the two approaches are shown to be related in a formal mathematical sense the text presents them separately as their relevant algorithm design issues are distinct and give rise to different performance capabilities Together with algorithm design the text demonstrates the underlying robustness of the paradigm and also includes new control laws that are capable of incorporating input and output constraints enable the algorithm to reconfigure systematically in order to meet the requirements of different reference and auxiliary signals and also to support new properties such as spectral annihilation Iterative Learning Control will interest academics and graduate students working in control who will find it a useful reference to the current status of a powerful and increasingly popular method of control The depth of background theory and links to practical systems will be of use to engineers responsible for precision repetitive processes

Real-time Iterative Learning Control Jian-Xin Xu, Sanjib K. Panda, Tong Heng Lee, 2008-12-12 Real time Iterative Learning Control demonstrates how the latest advances in iterative learning control ILC can be applied to a number of plants widely encountered in practice The book gives a systematic introduction to real time ILC design and source of illustrative case studies for ILC problem solving the fundamental concepts schematics configurations and generic guidelines

for ILC design and implementation are enhanced by a well selected group of representative simple and easy to learn example applications Key issues in ILC design and implementation in linear and nonlinear plants pervading mechatronics and batch processes are addressed in particular ILC design in the continuous and discrete time domains design in the frequency and time domains design with problem specific performance objectives including robustness and optimality design in a modular approach by integration with other control techniques and design by means of classical tools based on Bode plots and state space

Iterative Learning Control for Systems with Iteration-Varying Trial Lengths Dong Shen,Xuefang Li,2019-01-29 This book presents a comprehensive and detailed study on iterative learning control ILC for systems with iteration varying trial lengths Instead of traditional ILC which requires systems to repeat on a fixed time interval this book focuses on a more practical case where the trial length might randomly vary from iteration to iteration The iteration varying trial lengths may be different from the desired trial length which can cause redundancy or dropouts of control information in ILC making ILC design a challenging problem The book focuses on the synthesis and analysis of ILC for both linear and nonlinear systems with iteration varying trial lengths and proposes various novel techniques to deal with the precise tracking problem under non repeatable trial lengths such as moving window switching system and searching based moving average operator It not only discusses recent advances in ILC for systems with iteration varying trial lengths but also includes numerous intuitive figures to allow readers to develop an in depth understanding of the intrinsic relationship between the incomplete information environment and the essential tracking performance This book is intended for academic scholars and engineers who are interested in learning about control data driven control networked control systems and related fields It is also a useful resource for graduate students in the above field

Iterative Learning Control for Multi-agent Systems Coordination Shiping Yang,Jian-Xin Xu,Xuefang Li,Dong Shen,2017-06-12 A timely guide using iterative learning control ILC as a solution for multi agent systems MAS challenges showcasing recent advances and industrially relevant applications Explores the synergy between the important topics of iterative learning control ILC and multi agent systems MAS Concisely summarizes recent advances and significant applications in ILC methods for power grids sensor networks and control processes Covers basic theory rigorous mathematics as well as engineering practice

Linear and Nonlinear Iterative Learning Control Jian-Xin Xu,Ying Tan,2003-09-04 This monograph summarizes the recent achievements made in the field of iterative learning control The book is self contained in theoretical analysis and can be used as a reference or textbook for a graduate level course as well as for self study It opens a new avenue towards a new paradigm in deterministic learning control theory accompanied by detailed examples

Iterative Learning Control Algorithms and Experimental Benchmarking Eric Rogers,Bing Chu,Christopher Freeman,Paul Lewin,2023-01-17 Iterative Learning CONTROL ALGORITHMS AND EXPERIMENTAL BENCHMARKING Iterative Learning Control Algorithms and Experimental Benchmarking Presents key cutting edge research into the use of iterative learning control The book discusses the main methods of iterative learning

control ILC and its interactions as well as comparator performance that is so crucial to the end user The book provides integrated coverage of the major approaches to date in terms of basic systems theoretic properties design algorithms and experimentally measured performance as well as the links with repetitive control and other related areas Key features Provides comprehensive coverage of the main approaches to ILC and their relative advantages and disadvantages Presents the leading research in the field along with experimental benchmarking results Demonstrates how this approach can extend out from engineering to other areas and in particular new research into its use in healthcare systems rehabilitation robotics The book is essential reading for researchers and graduate students in iterative learning control repetitive control and more generally control systems theory and its applications

Practical Iterative Learning Control with Frequency Domain Design and Sampled Data Implementation Danwei Wang,Yongqiang Ye,Bin Zhang,2014-06-19 This book is on the iterative learning control ILC with focus on the design and implementation We approach the ILC design based on the frequency domain analysis and address the ILC implementation based on the sampled data methods This is the first book of ILC from frequency domain and sampled data methodologies The frequency domain design methods offer ILC users insights to the convergence performance which is of practical benefits This book presents a comprehensive framework with various methodologies to ensure the learnable bandwidth in the ILC system to be set with a balance between learning performance and learning stability The sampled data implementation ensures effective execution of ILC in practical dynamic systems The presented sampled data ILC methods also ensure the balance of performance and stability of learning process Furthermore the presented theories and methodologies are tested with an ILC controlled robotic system The experimental results show that the machines can work in much higher accuracy than a feedback control alone can offer With the proposed ILC algorithms it is possible that machines can work to their hardware design limits set by sensors and actuators The target audience for this book includes scientists engineers and practitioners involved in any systems with repetitive operations

Optimal Iterative Learning Control Bing Chu,David H. Owens,2025-07-14 This book introduces an optimal iterative learning control ILC design framework from the end user's point of view Its central theme is the understanding of model dynamics the construction of a procedure for systematic input updating and their contribution to successful algorithm design The authors discuss the many applications of ILC in industrial systems applications such as robotics and mechanical testing The text covers a number of optimal ILC design methods including gradient based and norm optimal ILC Their convergence properties are described and detailed design guidelines including performance improvement mechanisms are presented Readers are given a clear picture of the nature of ILC and the benefits of the optimization based approach from the conceptual and mathematical foundations of the problem of algorithm construction to the impact of available parameters in making acceleration of algorithmic convergence possible Three case studies on robotic platforms an electro mechanical machine and robot assisted stroke rehabilitation are included to demonstrate the application of these methods in the real world With its emphasis on basic

concepts detailed design guidelines and examples of benefits Optimal Iterative Learning Control will be of value to practising engineers and academic researchers alike **Iterative Learning Control with Passive Incomplete Information** Dong Shen, 2018-04-16 This book presents an in depth discussion of iterative learning control ILC with passive incomplete information highlighting the incomplete input and output data resulting from practical factors such as data dropout transmission disorder communication delay etc a cutting edge topic in connection with the practical applications of ILC It describes in detail three data dropout models the random sequence model Bernoulli variable model and Markov chain model for both linear and nonlinear stochastic systems Further it proposes and analyzes two major compensation algorithms for the incomplete data namely the intermittent update algorithm and successive update algorithm Incomplete information environments include random data dropout random communication delay random iteration varying lengths and other communication constraints With numerous intuitive figures to make the content more accessible the book explores several potential solutions to this topic ensuring that readers are not only introduced to the latest advances in ILC for systems with random factors but also gain an in depth understanding of the intrinsic relationship between incomplete information environments and essential tracking performance It is a valuable resource for academics and engineers as well as graduate students who are interested in learning about control data driven control networked control systems and related fields

Taming Heterogeneity and Complexity of Embedded Control Françoise Lamnabhi-Lagarri, Antonio Loria, Elena Panteley, Salah Laghrouche, 2013-05-21 This book gathers together a selection of papers presented at the Joint CTS HYCON Workshop on Nonlinear and Hybrid Control held at the Paris Sorbonne France 10 12 July 2006 The main objective of the Workshop was to promote the exchange of ideas and experiences and reinforce scientific contacts in the large multidisciplinary area of the control of nonlinear and hybrid systems *Precision Motion Control* Kok Kiong Tan, Tong Heng Lee, Sunan Huang, 2007-11-29 Precision Motion Control focuses on enabling technologies for precision engineering issues of direct importance to be addressed in the overall system design and realization precision instrumentation and measurement geometrical calibration and compensation and motion control It is a compilation of the most important results and publications from a major project that develops a state of the art high speed ultra precision robotic system The second edition has been edited and rewritten throughout with the following particular areas being expanded or added piezoelectric actuators fine movement control gantry stage control interpolation of quadrature encoder signals geometrical error modelling for single dual and general XY axis stages By providing detailed experimental verifications of the material developed a comprehensive and thorough treatment of the subject matter accessible to a broad base of readers ranging from academics to practitioners is provided *The Control Handbook (three volume set)* William S. Levine, 2018-10-08 At publication The Control Handbook immediately became the definitive resource that engineers working with modern control systems required Among its many accolades that first edition was cited by the AAP as the Best Engineering Handbook of

1996 Now 15 years later William Levine has once again compiled the most comprehensive and authoritative resource on control engineering He has fully reorganized the text to reflect the technical advances achieved since the last edition and has expanded its contents to include the multidisciplinary perspective that is making control engineering a critical component in so many fields Now expanded from one to three volumes The Control Handbook Second Edition brilliantly organizes cutting edge contributions from more than 200 leading experts representing every corner of the globe They cover everything from basic closed loop systems to multi agent adaptive systems and from the control of electric motors to the control of complex networks Progressively organized the three volume set includes Control System Fundamentals Control System Applications Control System Advanced Methods Any practicing engineer student or researcher working in fields as diverse as electronics aeronautics or biomedicine will find this handbook to be a time saving resource filled with invaluable formulas models methods and innovative thinking In fact any physicist biologist mathematician or researcher in any number of fields developing or improving products and systems will find the answers and ideas they need As with the first edition the new edition not only stands as a record of accomplishment in control engineering but provides researchers with the means to make further advances

Advances in Automation, Signal Processing, Instrumentation, and Control Venkata Lakshmi Narayana Komanapalli,N. Sivakumaran,Santoshkumar Hampannavar,2021-03-04 This book presents the select proceedings of the International Conference on Automation Signal Processing Instrumentation and Control i CASIC 2020 The book mainly focuses on emerging technologies in electrical systems IoT based instrumentation advanced industrial automation and advanced image and signal processing It also includes studies on the analysis design and implementation of instrumentation systems and high accuracy and energy efficient controllers The contents of this book will be useful for beginners researchers as well as professionals interested in instrumentation and control and other allied fields

The Control Handbook William S. Levine,2018-10-08 At publication The Control Handbook immediately became the definitive resource that engineers working with modern control systems required Among its many accolades that first edition was cited by the AAP as the Best Engineering Handbook of 1996 Now 15 years later William Levine has once again compiled the most comprehensive and authoritative resource on control engineering He has fully reorganized the text to reflect the technical advances achieved since the last edition and has expanded its contents to include the multidisciplinary perspective that is making control engineering a critical component in so many fields Now expanded from one to three volumes The Control Handbook Second Edition organizes cutting edge contributions from more than 200 leading experts The second volume Control System Applications includes 35 entirely new applications organized by subject area Covering the design and use of control systems this volume includes applications for Automobiles including PEM fuel cells Aerospace Industrial control of machines and processes Biomedical uses including robotic surgery and drug discovery and development Electronics and communication networks Other applications are included in a section that reflects the multidisciplinary nature of control

system work These include applications for the construction of financial portfolios earthquake response control for civil structures quantum estimation and control and the modeling and control of air conditioning and refrigeration systems As with the first edition the new edition not only stands as a record of accomplishment in control engineering but provides researchers with the means to make further advances Progressively organized the other two volumes in the set include Control System Fundamentals Control System Advanced Methods **Plastics Process Analysis, Instrumentation, and Control** Johannes Karl Fink, 2021-03-30 This book focuses on plastics process analysis instrumentation for modern manufacturing in the plastics industry Process analysis is the starting point since plastics processing is different from processing of metals ceramics and other materials Plastics materials show unique behavior in terms of heat transfer fluid flow viscoelastic behavior and a dependence of the previous time temperature and shear history which determines how the material responds during processing and its end use Many of the manufacturing processes are continuous or cyclical in nature The systems are flow systems in which the process variables such as time temperature position melt and hydraulic pressure must be controlled to achieve a satisfactory product which is typically specified by critical dimensions and physical properties which vary with the processing conditions Instrumentation has to be selected so that it survives the harsh manufacturing environment of high pressures temperatures and shear rates and yet it has to have a fast response to measure the process dynamics At many times the measurements have to be in a non contact mode so as not to disturb the melt or the finished product Plastics resins are reactive systems The resins will degrade if the process conditions are not controlled Analysis of the process allows one to strategize how to minimize degradation and optimize end use properties *Iterative Learning Control for Equations with Fractional Derivatives and Impulses* JinRong Wang, Shengda Liu, Michal Fečkan, 2021-12-10 This book introduces iterative learning control ILC and its applications to the new equations such as fractional order equations impulsive equations delay equations and multi agent systems which have not been presented in other books on conventional fields ILC is an important branch of intelligent control which is applicable to robotics process control and biological systems The fractional version of ILC updating laws and formation control are presented in this book ILC design for impulsive equations and inclusions are also established The broad variety of achieved results with rigorous proofs and many numerical examples make this book unique This book is useful for graduate students studying ILC involving fractional derivatives and impulsive conditions as well as for researchers working in pure and applied mathematics physics mechanics engineering biology and related disciplines *Robust Iterative Learning Control of Industrial Batch Systems* Tao Liu, Shoulin Hao, Youqing Wang, Dewei Li, 2025-10-27 This book offers advanced iterative learning control ILC and optimization methods for industrial batch systems facilitating engineering applications subject to time and batch varying process uncertainties that could not be effectively addressed by the existing ILC methods In particular advanced ILC designs based on the classical proportional integral derivative PID control loop are presented for the convenience of application

which could not only realize perfect tracking of the desired output trajectory under repetitive process uncertainties and disturbance but also maintain robust tracking against time varying uncertainties and disturbance Moreover optimization based ILC designs are provided to deal with the input and or output constraints of batch process operation based on the mode predictive control MPC principle for process optimization Furthermore predictor based ILC designs are given to deal with time delay in the process input state or output as often encountered in practice which could obtain evidently improved control performance compared to the developed ILC methods mainly devoted to delay free batch processes In addition data driven ILC methods are also presented for application to batch operation systems with unknown dynamics and time varying uncertainties Benchmark examples from the existing literature are used to demonstrate the advantages of the proposed ILC methods along with real applications to industrial injection molding machines 6 degree of freedom robotic manipulator and refrigerated heating circulators of pharmaceutical crystallizers This book will be a valuable source of information for control engineers and researchers in industrial process control theory and engineering field It can also be used as an advanced textbook for undergraduate and graduate students in control engineering process system engineering chemical engineering mechanical engineering electrical engineering biomedical engineering and industrial automation engineering

CONTROL SYSTEMS, ROBOTICS AND AUTOMATION – Volume X Heinz D. Unbehauen, 2009-10-11 This Encyclopedia of Control Systems Robotics and Automation is a component of the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias This 22 volume set contains 240 chapters each of size 5000 30000 words with perspectives applications and extensive illustrations It is the only publication of its kind carrying state of the art knowledge in the fields of Control Systems Robotics and Automation and is aimed by virtue of the several applications at the following five major target audiences University and College Students Educators Professional Practitioners Research Personnel and Policy Analysts Managers and Decision Makers and NGOs

Precision Motion Control Kok K. Tan, Tong H. Lee, Huifang Dou, Sunan Huang, 2013-04-17 Precision manufacturing is a development that has been gathering momentum over the last century and accelerating over the last 25 years in terms of research development and application to product innovation The driving force in this development arises from requirements for much higher performance of products higher reliability longer life lower cost and miniaturization This development is widely known as precision engineering and today it is generally defined as manufacturing to tolerances which are better than one part in 105 Applications are abound and can be found in various semiconductor processes e g lithography wafer probing inspection Coordinate Measuring Machines CMMs and precision metrology systems e g Scanning Probe Microscopy SPM and robot machine tools to carry out micro assembly e g MEMS and delicate short wavelength laser processes As an enabling technology for precision engineering precision instrumentation and measurement geometrical calibration and compensation and motion control are directly important issues to be addressed in the overall system design and realization This book is focused on these aspects of

precision engineering It is a compilation of the major results and publications from a major project which develop a state of the art high speed ultra precision robotic system A comprehensive and thorough treatment of the subject matter is provided in a manner that is amenable to a broad base of readers ranging from the academics to the practitioners by providing detailed experimental verifications of the developed materials

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