

Model Predictive Control: Theory and Design

James B. Rawlings
David Q. Mayne



Model Predictive Control Theory And Design

Matthias A. Müller



Model Predictive Control Theory And Design:

Model Predictive Control James Blake Rawlings, David Q. Mayne, 2009 **Model Predictive Control** James Blake Rawlings, David Q. Mayne, Moritz Diehl, 2017 **Model Predictive Control** Aris Daniilidis, Lars Grüne, Josef Haunschmied, Gernot Tragler, 2025-06-07 The book explores the field of model predictive control MPC It reports on the latest developments in MPC current applications and presents various subfields of MPC The book features topics such as uncertain and stochastic MPC variants learning and neural network approaches easy to use numerical implementations as well as multi agent systems and scheduling and coordination tasks While MPC is rooted in engineering science this book illustrates the potential of using MPC theory and methods in non engineering sciences and applications such as economics finance and environmental sciences Handbook of Model Predictive Control Saša V. Raković, William S. Levine, 2018-09-01 Recent developments in model predictive control promise remarkable opportunities for designing multi input multi output control systems and improving the control of single input single output systems This volume provides a definitive survey of the latest model predictive control methods available to engineers and scientists today The initial set of chapters present various methods for managing uncertainty in systems including stochastic model predictive control With the advent of affordable and fast computation control engineers now need to think about using computationally intensive controls so the second part of this book addresses the solution of optimization problems in real time for model predictive control The theory and applications of control theory often influence each other so the last section of Handbook of Model Predictive Control rounds out the book with representative applications to automobiles healthcare robotics and finance The chapters in this volume will be useful to working engineers scientists and mathematicians as well as students and faculty interested in the progression of control theory Future developments in MPC will no doubt build from concepts demonstrated in this book and anyone with an interest in MPC will find fruitful information and suggestions for additional reading **Model Predictive Control mit MATLAB und Simulink** Rainer Dittmar, 2019-12-04 Modellbasierte prädiktive Regelungen dienen der Lösung anspruchsvoller Aufgaben der Mehrgrößenregelung mit Beschränkungen der Stell- und Regelgrößen Sie werden in der Industrie in vielen Bereichen erfolgreich eingesetzt Mit der MPC Toolbox™ des Programmsystems MATLAB Simulink steht ein Werkzeug zur Verfügung das sowohl in der industriellen Praxis als auch an Universitäten und Hochschulen verwendet wird Das vorliegende Buch gibt einen Überblick über die Grundideen und Anwendungsvorteile des MPC Konzepts Es zeigt wie mit Hilfe der Toolbox MPC Regelungen entworfen eingestellt und simuliert werden können Ausgewählte Beispiele aus dem Bereich der Verfahrenstechnik demonstrieren mögliche Vorgehensweisen und vertiefen das Verständnis Das Buch richtet sich an in der Industrie tätige Ingenieure die MPC Regelungen planen entwickeln und betreiben aber auch an Studierende technischer Fachdisziplinen die in das Arbeitsgebiet MPC einsteigen wollen Model Predictive Control MPC is used to solve challenging multivariable constrained control problems MPC systems are successfully applied in many different branches of

industry The MPC Toolbox™ of MATLAB Simulink provides powerful tools for industrial MPC application but also for education and research at technical universities This book gives an overview of the basic ideas and advantages of the MPC concept It shows how MPC systems can be designed tuned and simulated using the MPC Toolbox Selected process engineering benchmark examples are used to demonstrate typical design approaches and help deepen the understanding of MPC technologies The book is aimed at engineers in industry interested in the development and application of MPC systems as well as students of different technical disciplines seeking an introduction into this field This book gives an overview of the basic ideas and advantages of the MPC concept It shows how MPC systems can be designed tuned and simulated using the MPC Toolbox Selected process engineering benchmark examples are used to demonstrate typical design approaches and help deepen the understanding of MPC technologies The book is aimed at engineers in industry interested in the development and application of MPC systems as well as students of different technical disciplines seeking an introduction into this field

Model Predictive Control of Wastewater Systems Carlos Ocampo-Martinez, 2010-10-01 The series Advances in Industrial Control aims to report and encourage technology transfer in control engineering The rapid development of control technology has an impact on all areas of the control discipline New theory new controllers actuators sensors new industrial processes computer methods new applications new philosophies new challenges Much of this development work resides in industrial reports feasibility study papers and the reports of advanced collaborative projects The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination The water and wastewater industry has undergone many changes in recent years Of particular importance has been a renewed emphasis on improving resource management with tighter regulatory controls setting new targets on pricing industry efficiency and loss reduction for both water and wastewater with more stringent environmental discharge conditions for wastewater Meantime the demand for water and wastewater services grows as the population increases and wishes for improved living conditions involving among other items domestic appliances that use water Consequently the installed infrastructure of the industry has to be continuously upgraded and extended and employed more effectively to accommodate the new demands both in throughput and in meeting the new regulatory conditions Investment in fixed infrastructure is capital intensive and slow to come on stream One outcome of these changes and demands is that the industry is examining the potential benefits of and in many cases using more advanced control systems

Model Predictive Control of High Power Converters and Industrial Drives Tobias Geyer, 2017-02-28 In this original book on model predictive control MPC for power electronics the focus is put on high power applications with multilevel converters operating at switching frequencies well below 1 kHz such as medium voltage drives and modular multi level converters Consisting of two main parts the first offers a detailed review of three phase power electronics electrical machines carrier based pulse width modulation optimized pulse patterns state of the art converter control methods and the

principle of MPC The second part is an in depth treatment of MPC methods that fully exploit the performance potential of high power converters These control methods combine the fast control responses of deadbeat control with the optimal steady state performance of optimized pulse patterns by resolving the antagonism between the two MPC is expected to evolve into the control method of choice for power electronic systems operating at low pulse numbers with multiple coupled variables and tight operating constraints it Model Predictive Control of High Power Converters and Industrial Drives will enable to reader to learn how to increase the power capability of the converter lower the current distortions reduce the filter size achieve very fast transient responses and ensure the reliable operation within safe operating area constraints Targeted at power electronic practitioners working on control related aspects as well as control engineers the material is intuitively accessible and the mathematical formulations are augmented by illustrations simple examples and a book companion website featuring animations Readers benefit from a concise and comprehensive treatment of MPC for industrial power electronics enabling them to understand implement and advance the field of high performance MPC schemes *New Directions on Model Predictive Control* Jinfeng Liu,Helen E Durand,2019-01-16 This book is a printed edition of the Special Issue New Directions on Model Predictive Control that was published in Mathematics **Distributed and economic model**

predictive control: beyond setpoint stabilization Matthias A. Müller,2014 In this thesis we study model predictive control MPC schemes for control tasks which go beyond the classical objective of setpoint stabilization In particular we consider two classes of such control problems namely distributed MPC for cooperative control in networks of multiple interconnected systems and economic MPC where the main focus is on the optimization of some general performance criterion which is possibly related to the economics of a system The contributions of this thesis are to analyze various systems theoretic properties occurring in these type of control problems and to develop distributed and economic MPC schemes with certain desired closed loop guarantees To be more precise in the field of distributed MPC we propose different algorithms which are suitable for general cooperative control tasks in networks of interacting systems We show that the developed distributed MPC frameworks are such that the desired cooperative goal is achieved while coupling constraints between the systems are satisfied Furthermore we discuss implementation and scalability issues for the derived algorithms as well as the necessary communication requirements between the systems In the field of economic MPC the contributions of this thesis are threefold Firstly we analyze a crucial dissipativity condition in particular its necessity for optimal steady state operation of a system and its robustness with respect to parameter changes Secondly we develop economic MPC schemes which also take average constraints into account Thirdly we propose an economic MPC framework with self tuning terminal cost and a generalized terminal constraint and we show how self tuning update rules for the terminal weight can be derived such that desirable closed loop performance bounds can be established **Distributed Model Predictive Control Made Easy** José M. Maestre,Rudy R. Negenborn,2013-11-10 The rapid evolution of computer science communication and

information technology has enabled the application of control techniques to systems beyond the possibilities of control theory just a decade ago Critical infrastructures such as electricity water traffic and intermodal transport networks are now in the scope of control engineers The sheer size of such large scale systems requires the adoption of advanced distributed control approaches Distributed model predictive control MPC is one of the promising control methodologies for control of such systems This book provides a state of the art overview of distributed MPC approaches while at the same time making clear directions of research that deserve more attention The core and rationale of 35 approaches are carefully explained Moreover detailed step by step algorithmic descriptions of each approach are provided These features make the book a comprehensive guide both for those seeking an introduction to distributed MPC as well as for those who want to gain a deeper insight in the wide range of distributed MPC techniques available

Model Predictive Control for Nonlinear Continuous-Time Systems with and Without Time-Delays Marcus Reble, 2013 The objective of this thesis is the development of novel model predictive control MPC schemes for nonlinear continuous time systems with and without time delays in the states which guarantee asymptotic stability of the closed loop The most well studied MPC approaches with guaranteed stability use a control Lyapunov function as terminal cost Since the actual calculation of such a function can be difficult it is desirable to replace this assumption by a less restrictive controllability assumption For discrete time systems the latter assumption has been used in the literature for the stability analysis of so called unconstrained MPC i.e. MPC without terminal cost and terminal constraints The contributions of this thesis are twofold In the first part we propose novel MPC schemes with guaranteed stability based on a controllability assumption whereas we extend different MPC schemes with guaranteed stability to nonlinear time delay systems in the second part In the first part of this thesis we derive explicit stability conditions on the prediction horizon as well as performance guarantees for unconstrained MPC Starting from this result we propose novel alternative MPC formulations based on combinations of the controllability assumption with terminal cost and terminal constraints One of the main contributions is the development of a unifying MPC framework which allows to consider both MPC schemes with terminal cost and terminal constraints as well as unconstrained MPC as limit cases of our framework In the second part of this thesis we show that several MPC schemes with and without terminal constraints can be extended to nonlinear time delay systems Due to the infinite dimensional nature of these systems the problem is more involved and additional assumptions are required in the controller design We investigate different MPC schemes with and without terminal constraints and or terminal cost terms and derive novel stability conditions Furthermore we pay particular attention to the calculation of the involved control design parameters

Model Predictive Control Corinne Wade, 2015 Although industrial processes are inherently nonlinear many contributions for controller design for those plants are based on the assumption of a linear model of the system However in some cases it is difficult to represent a given process using a linear model Model Predictive Control MPC is an optimal control approach which can effectively deal with constraints and

multivariable processes in industries Because of its advantages MPC has been widely applied in automotive and process control communities This book discusses the theory practices and future challenges of model predictive control *Relaxed Barrier Function Based Model Predictive Control* Christian Feller,2017 In this thesis we introduce the novel concept of relaxed barrier function based model predictive control and present a comprehensive theoretical and algorithmic framework for the design analysis and implementation of relaxed barrier function based MPC approaches Instead of treating the underlying optimization as an idealized static map a key motive of the MPC results and algorithms presented in this thesis is to study the interconnected dynamics of controlled plant and iterative optimization algorithm in an integrated barrier function based framework and to analyze the resulting overall closed loop system both from a systems theoretic and algorithmic perspective One of the presented main results is a novel class of barrier function based anytime MPC algorithms that guarantee important properties of the closed loop system independently of the number of optimization algorithm iterations that are performed at each sampling step The obtained theoretical results are illustrated by various numerical examples and benchmark tests as well as by an experimental case study in which the proposed class of barrier function based MPC algorithms is applied to the predictive control of a self driving car *Beitrag zu iterativ lernenden modellprädiktiven Regelungen* Fabian Kennel,2017 In der Industrie laufen viele Prozesse zyklisch und damit wiederholend ab Eine hohe Regelgüte ist hierbei unabdingbar Daher kommen iterativ lernende Regelungsmethoden zum Einsatz welche die Regelung des Prozesses zyklisch verbessern In dieser Dissertation werden iterativ lernende modellprädiktive Regelungsverfahren vorgestellt Die entwickelten Methoden ermöglichen durch ihre modellbasierte Struktur eine zyklische Steigerung der Regelgüte bei gleichzeitiger Berücksichtigung der Systembeschränkungen Zyklische unbekannte Störungen und Dynamiken lassen sich hiermit iterativ erlernen und unterdrücken Eine Robustifizierung der Verfahren gegen Messrauschen sowie Unsicherheiten wird in dieser Arbeit aufgezeigt Rechenzeit und Speicherbedarf stellen die größten Herausforderungen der optimierungsbasierten Verfahren dar Verschiedene effiziente Ansätze zur Reduktion von Speicher und Rechenbedarf werden in der Dissertation dargelegt In den optimierungsbasierten Entwurf lassen sich weitere Optimierungsziele einbinden Gerade für industrielle Prozesse stellt eine Reduktion des Energiebedarfs sowie eine Reduktion der Prozesszeiten ein wichtiges Optimierungskriterium dar Diese Kriterien können in einfacher Weise in die entwickelten Verfahren integriert werden Je nach Prozess sind Energieeinsparungen von über 50% realisierbar Die Prozesszeiten lassen sich teilweise mehr als halbieren Die Verfahren selbst wurden an drei Beispielsystemen praktisch erprobt Die Ergebnisse sind zufriedenstellend und für die Industrie von praktischer Relevanz **Emerging Electronics and Automation** Peter Han Joo Chong,Akhtar Kalam,Antonio Pascoal,Manas Kumar Bera,2022-11-09 This book constitutes peer reviewed proceedings of the International Conference on Emerging Electronics and Automation E2A 2021 The book presents new ideas research findings and novel techniques in the fields of sensors and instrumentation automation and control artificial intelligence MEMS sensors soft

computing signal processing and communication It includes contributions received from both academia and industry The proceedings will be helpful for beginners as well as advanced researchers in the area of automation and other allied fields

Computationally Efficient Model Predictive Control Algorithms Maciej Ławryńczuk, 2014-01-24 This book thoroughly discusses computationally efficient suboptimal Model Predictive Control MPC techniques based on neural models The subjects treated include A few types of suboptimal MPC algorithms in which a linear approximation of the model or of the predicted trajectory is successively calculated on line and used for prediction Implementation details of the MPC algorithms for feed forward perceptron neural models neural Hammerstein models neural Wiener models and state space neural models The MPC algorithms based on neural multi models inspired by the idea of predictive control The MPC algorithms with neural approximation with no on line linearization The MPC algorithms with guaranteed stability and robustness Cooperation between the MPC algorithms and set point optimization Thanks to linearization or neural approximation the presented suboptimal algorithms do not require demanding on line nonlinear optimization The presented simulation results demonstrate high accuracy and computational efficiency of the algorithms For a few representative nonlinear benchmark processes such as chemical reactors and a distillation column for which the classical MPC algorithms based on linear models do not work properly the trajectories obtained in the suboptimal MPC algorithms are very similar to those given by the ideal MPC algorithm with on line nonlinear optimization repeated at each sampling instant At the same time the suboptimal MPC algorithms are significantly less computationally demanding *Modeling and Control of Precision Actuators* Tan Kok Kiong, Huang Sunan, 2018-10-08 Modeling and Control of Precision Actuators explores new technologies that can ultimately be applied in a myriad of industries It covers dynamical analysis of precise actuators and strategies of design for various control applications The book addresses four main schemes modeling and control of precise actuators nonlinear control of precise actuators including sliding mode control and neural network feedback control fault detection and fault tolerant control and advanced air bearing control It covers application issues in the modeling and control of precise actuators providing several interesting case studies for more application oriented readers Introduces the driving forces behind precise actuators Describes nonlinear dynamics of precise actuators and their mathematical forms including hysteresis creep friction and force ripples Presents the control strategies for precise actuators based on Preisach model as well as creep dynamics Develops relay feedback techniques for identifying nonlinearities such as friction and force ripples Discusses a MPC approach based on piecewise affine models which emulate the frictional effects in the precise actuator Covers the concepts of air bearing stages with the corresponding control method Provides a set of schemes suitable for fault detection and accommodation control of mechanical systems Emphasizing design theory and control strategies the book includes simulation and practical examples for each chapter covers precise actuators such as piezo motors coil motors air bearing motors and linear motors discusses integration among different technologies and includes three case studies in real

projects The book concludes by linking design methods and their applications emphasizing the key issues involved and how to implement the precision motion control tasks in a practical system It provides a concise and comprehensive source of the state of the art developments and results for modeling and control of precise actuators **Performance and Constraint**

Satisfaction in Robust Economic Model Predictive Control Florian A. Bayer ,2017 In this thesis we develop a novel framework for model predictive control MPC which combines the concepts of robust MPC and economic MPC The goal of this thesis is to develop and analyze MPC schemes for nonlinear discrete time systems which explicitly consider the influence of disturbances on arbitrary performance criteria Instead of regarding the two aspects separately we propose robust economic MPC approaches that integrate information which is available about the disturbance directly into the economic framework In more detail we develop three concepts which differ in which information about the disturbance is used and how this information is taken into account Furthermore we provide a thorough theoretical analysis for each of the three approaches To this end we present results on the asymptotic average performance as well as on optimal operating regimes Optimal operating regimes are closely related to the notion of dissipativity which is therefore analyzed for the presented concepts Under suitable assumptions results on necessity and sufficiency of dissipativity for optimal steady state operation are established for all three robust economic MPC concepts A detailed discussion is provided which compares the different performance statements derived for the approaches as well as the respective notions of dissipativity **Nostradamus**

2014: Prediction, Modeling and Analysis of Complex Systems Ivan Zelinka,Ponnuthurai Nagaratnam Suganthan,Guanrong Chen,Vaclav Snasel,Ajith Abraham,Otto RöSSLer,2014-06-09 The prediction of behavior of complex systems analysis and modeling of its structure is a vitally important problem in engineering economy and generally in science today Examples of such systems can be seen in the world around us including our bodies and of course in almost every scientific discipline including such exotic domains as the earth s atmosphere turbulent fluids economics exchange rate and stock markets population growth physics control of plasma information flow in social networks and its dynamics chemistry and complex networks To understand such complex dynamics which often exhibit strange behavior and to use it in research or industrial applications it is paramount to create its models For this purpose there exists a rich spectrum of methods from classical such as ARMA models or Box Jenkins method to modern ones like evolutionary computation neural networks fuzzy logic geometry deterministic chaos amongst others This proceedings book is a collection of accepted papers of the Nostradamus conference that has been held in Ostrava Czech Republic in June 2014 This book also includes outstanding keynote lectures by distinguished guest speakers Ren Lozi France Ponnuthurai Nagaratnam Suganthan Singapore and Lars Nolle Germany The main aim of the conference was to create a periodical possibility for students academics and researchers to exchange their ideas and novel research methods This conference establishes a forum for presentation and discussion of recent research trends in the area of applications of various predictive methods Control and Information Sciences I.

Thirunavukkarasu, Roshan Kumar, 2024-10-28 This book presents the select proceedings of the Control Instrumentation and System Conference CISCON 2023 held at Manipal Institute of Technology MAHE Manipal. It examines a broad spectrum covering the latest trends in instrumentation, sensors and systems, and industrial automation and control. The topics covered include image and signal processing, robotics, renewable energy, power systems and power drives, performance attributes of MEMS, multi-sensor data fusion, machine learning, optimization techniques, process control, safety monitoring, safety-critical control, supervisory control, system modeling, and virtual instrumentation. The book is a valuable reference for researchers and professionals interested in sensors, adaptive management, automation and control, and allied fields.

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