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Model Predictive Control in the Process Industry *Practical Design and Application of Model Predictive Control* **Model-Based Predictive Control** **Model Predictive Control** *Model Predictive Control System Design and Implementation Using MATLAB®* Model Predictive Control Handbook of Model Predictive Control **Model Predictive Control Nonlinear Model Predictive Control** *Receding Horizon Control Predictive Control for Linear and Hybrid Systems* **Dynamic Modeling, Predictive Control and Performance Monitoring** Model-Based Predictive Control Predictive Control Handbook of Model Predictive Control *Model Predictive Control of High Power Converters and Industrial Drives* Recent Advances in Model Predictive Control **Nonlinear Model Predictive Control** *Model Predictive Control for Doubly-Fed Induction Generators and Three-Phase Power Converters* Assessment and Future Directions of Nonlinear Model Predictive Control *Nonlinear Model Predictive Control* **Model Predictive Control** *Advanced Model Predictive Control Distributed Model Predictive Control Made Easy* **Model Predictive Control Modern Predictive Control** *Automotive Model Predictive Control* **Model Predictive Vibration Control** **Model Predictive Control for Constrained Nonlinear Systems** **Explicit Nonlinear Model Predictive Control** **Distributed Model Predictive Control for Plant-Wide Systems** Model Predictive Control mit MATLAB und

Simulink Model Predictive Control for Nonlinear Continuous-Time Systems with and Without Time-Delays Model Predictive Control for AC Motors Model Predictive Control of Wastewater Systems Model Predictive Control Predictive Control of Power Converters and Electrical Drives *Economic Model Predictive Control* Model Predictive Control in the Process Industry
Computationally Efficient Model Predictive Control Algorithms

Model Predictive Control is an important technique used in the process control industries. It has developed considerably in the last few years, because it is the most general way of posing the process control problem in the time domain. The Model Predictive Control formulation integrates optimal control, stochastic control, control of processes with dead time, multivariable control and future references. The finite control horizon makes it possible to handle constraints and non linear processes in general which are frequently found in industry. Focusing on implementation issues for Model Predictive Controllers in industry, it fills the gap between the empirical way practitioners use control algorithms and the sometimes abstractly formulated techniques developed by researchers. The text is firmly based on material from lectures given to senior undergraduate and graduate students and articles written by the authors. Automotive control has developed over the decades from an auxiliary technology to a key element without which the actual performances, emission, safety and consumption targets could not be met. Accordingly, automotive control has been increasing its authority and responsibility – at the price of complexity and difficult tuning. The progressive evolution has been mainly led by specific applications and short term targets, with the consequence that automotive control is to a very large extent more heuristic than systematic. Product requirements are still increasing and new challenges are coming from potentially huge markets like India and China, and against this background there is wide consensus both in

the industry and academia that the current state is not satisfactory. Model-based control could be an approach to improve performance while reducing development and tuning times and possibly costs. Model predictive control is a kind of model-based control design approach which has experienced a growing success since the middle of the 1980s for “slow” complex plants, in particular of the chemical and process industry. In the last decades, several developments have allowed using these methods also for “fast” systems and this has supported a growing interest in its use also for automotive applications, with several promising results reported. Still there is no consensus on whether model predictive control with its high requirements on model quality and on computational power is a sensible choice for automotive control. This book presents general methods for the design of economic model predictive control (EMPC) systems for broad classes of nonlinear systems that address key theoretical and practical considerations including recursive feasibility, closed-loop stability, closed-loop performance, and computational efficiency. Specifically, the book proposes: Lyapunov-based EMPC methods for nonlinear systems; two-tier EMPC architectures that are highly computationally efficient; and EMPC schemes handling explicitly uncertainty, time-varying cost functions, time-delays and multiple-time-scale dynamics. The proposed methods employ a variety of tools ranging from nonlinear systems analysis, through Lyapunov-based control techniques to nonlinear dynamic optimization. The applicability and performance of the proposed methods are demonstrated through a number of chemical process examples. The book presents state-of-the-art methods for the design of economic model predictive control systems for chemical processes. In addition to being mathematically rigorous, these methods accommodate key practical issues, for example, direct optimization of process economics, time-varying economic cost functions and computational efficiency. Numerous comments and remarks providing fundamental understanding of the

merging of process economics and feedback control into a single framework are included. A control engineer can easily tailor the many detailed examples of industrial relevance given within the text to a specific application. The authors present a rich collection of new research topics and references to significant recent work making Economic Model Predictive Control an important source of information and inspiration for academics and graduate students researching the area and for process engineers interested in applying its ideas. This book offers readers a thorough and rigorous introduction to nonlinear model predictive control (NMPC) for discrete-time and sampled-data systems. NMPC schemes with and without stabilizing terminal constraints are detailed, and intuitive examples illustrate the performance of different NMPC variants. NMPC is interpreted as an approximation of infinite-horizon optimal control so that important properties like closed-loop stability, inverse optimality and suboptimality can be derived in a uniform manner. These results are complemented by discussions of feasibility and robustness. An introduction to nonlinear optimal control algorithms yields essential insights into how the nonlinear optimization routine—the core of any nonlinear model predictive controller—works. Accompanying software in MATLAB® and C++ (downloadable from extras.springer.com/), together with an explanatory appendix in the book itself, enables readers to perform computer experiments exploring the possibilities and limitations of NMPC. The second edition has been substantially rewritten, edited and updated to reflect the significant advances that have been made since the publication of its predecessor, including: • a new chapter on economic NMPC relaxing the assumption that the running cost penalizes the distance to a pre-defined equilibrium; • a new chapter on distributed NMPC discussing methods which facilitate the control of large-scale systems by splitting up the optimization into smaller subproblems; • an extended discussion of stability and performance using approximate updates rather than full

optimization; • replacement of the pivotal sufficient condition for stability without stabilizing terminal conditions with a weaker alternative and inclusion of an alternative and much simpler proof in the analysis; and • further variations and extensions in response to suggestions from readers of the first edition. Though primarily aimed at academic researchers and practitioners working in control and optimization, the text is self-contained, featuring background material on infinite-horizon optimal control and Lyapunov stability theory that also makes it accessible for graduate students in control engineering and applied mathematics. This book introduces how to improve the accuracy and robustness of model predictive control. Firstly, the disturbance observation- and compensation-based method is developed. Secondly, direct parameter identification methods are developed. Thirdly, the seldom-focused-on issues such as sampling and delay problems are solved in this book. Overall, this book solves the problems in a systematic and innovative way. Chapter 2 is available open access under a Creative Commons Attribution 4.0 International License via link.springer.com Model Predictive Control (MPC), the dominant advanced control approach in industry over the past twenty-five years, is presented comprehensively in this unique book. With a simple, unified approach, and with attention to real-time implementation, it covers predictive control theory including the stability, feasibility, and robustness of MPC controllers. The theory of explicit MPC, where the nonlinear optimal feedback controller can be calculated efficiently, is presented in the context of linear systems with linear constraints, switched linear systems, and, more generally, linear hybrid systems. Drawing upon years of practical experience and using numerous examples and illustrative applications, the authors discuss the techniques required to design predictive control laws, including algorithms for polyhedral manipulations, mathematical and multiparametric programming and how to validate the theoretical properties and to implement predictive control policies.

The most important algorithms feature in an accompanying free online MATLAB toolbox, which allows easy access to sample solutions. Predictive Control for Linear and Hybrid Systems is an ideal reference for graduate, postgraduate and advanced control practitioners interested in theory and/or implementation aspects of predictive control. 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. Model Predictive Control of High Power Converters and Industrial Drives will enable the 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. 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. 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 System Design and Implementation Using MATLAB® proposes methods for design and implementation of MPC systems using basis functions that confer the following advantages: - continuous- and discrete-time MPC problems solved in similar design frameworks; - a parsimonious parametric representation of the control trajectory gives rise to computationally efficient algorithms and better on-line performance; and - a more general discrete-time representation of MPC design that becomes identical to the traditional approach for an appropriate choice of parameters. After the theoretical presentation, coverage is given to three industrial applications. The subject of quadratic programming, often associated with the core optimization algorithms of MPC is also introduced and explained. The technical contents of this book is mainly based on advances in MPC using state-space models and basis functions. This volume includes numerous analytical examples and problems and MATLAB® programs and exercises. Easy-to-follow learning structure makes absorption of advanced material as pain-free as possible Introduces complete theories for stability and cost monotonicity for constrained and non-linear systems as well as for linear systems In co-ordination with MATLAB® files available from springeronline.com, exercises and examples give the student more practice in the predictive control and filtering techniques presented This book is a comprehensive introduction to model predictive control (MPC), including its basic principles and algorithms, system analysis and design methods, strategy developments and practical applications. The main contents of the book include an overview of the development trajectory and basic

principles of MPC, typical MPC algorithms, quantitative analysis of classical MPC systems, design and tuning methods for MPC parameters, constrained multivariable MPC algorithms and online optimization decomposition methods. Readers will then progress to more advanced topics such as nonlinear MPC and its related algorithms, the diversification development of MPC with respect to control structures and optimization strategies, and robust MPC. Finally, applications of MPC and its generalization to optimization-based dynamic problems other than control will be discussed.

Systematically introduces fundamental concepts, basic algorithms, and applications of MPC Includes a comprehensive overview of MPC development, emphasizing recent advances and modern approaches Features numerous MPC models and structures, based on rigorous research Based on the best-selling Chinese edition, which is a key text in China Predictive Control: Fundamentals and Developments is written for advanced undergraduate and graduate students and researchers specializing in control technologies. It is also a useful reference for industry professionals, engineers, and technicians specializing in advanced optimization control technology.

Real-time model predictive controller (MPC) implementation in active vibration control (AVC) is often rendered difficult by fast sampling speeds and extensive actuator-deformation asymmetry. If the control of lightly damped mechanical structures is assumed, the region of attraction containing the set of allowable initial conditions requires a large prediction horizon, making the already computationally demanding on-line process even more complex. Model Predictive Vibration Control provides insight into the predictive control of lightly damped vibrating structures by exploring computationally efficient algorithms which are capable of low frequency vibration control with guaranteed stability and constraint feasibility. In addition to a theoretical primer on active vibration damping and model predictive control, Model Predictive Vibration Control provides a guide through the necessary steps in

understanding the founding ideas of predictive control applied in AVC such as: · the implementation of computationally efficient algorithms · control strategies in simulation and experiment and · typical hardware requirements for piezoceramics actuated smart structures. The use of a simple laboratory model and inclusion of over 170 illustrations provides readers with clear and methodical explanations, making Model Predictive Vibration Control the ideal support material for graduates, researchers and industrial practitioners with an interest in efficient predictive control to be utilized in active vibration attenuation. During the past decade model predictive control (MPC), also referred to as receding horizon control or moving horizon control, has become the preferred control strategy for quite a number of industrial processes. There have been many significant advances in this area over the past years, one of the most important ones being its extension to nonlinear systems. This book gives an up-to-date assessment of the current state of the art in the new field of nonlinear model predictive control (NMPC). The main topic areas that appear to be of central importance for NMPC are covered, namely receding horizon control theory, modeling for NMPC, computational aspects of on-line optimization and application issues. The book consists of selected papers presented at the International Symposium on Nonlinear Model Predictive Control – Assessment and Future Directions, which took place from June 3 to 5, 1998, in Ascona, Switzerland. The book is geared towards researchers and practitioners in the area of control engineering and control theory. It is also suited for postgraduate students as the book contains several overview articles that give a tutorial introduction into the various aspects of nonlinear model predictive control, including systems theory, computations, modeling and applications. Nonlinear Model Predictive Control (NMPC) has become the accepted methodology to solve complex control problems related to process industries. The main motivation behind explicit NMPC is that an explicit state feedback law avoids

the need for executing a numerical optimization algorithm in real time. The benefits of an explicit solution, in addition to the efficient on-line computations, include also verifiability of the implementation and the possibility to design embedded control systems with low software and hardware complexity. This book considers the multi-parametric Nonlinear Programming (mp-NLP) approaches to explicit approximate NMPC of constrained nonlinear systems, developed by the authors, as well as their applications to various NMPC problem formulations and several case studies. The following types of nonlinear systems are considered, resulting in different NMPC problem formulations:

- Nonlinear systems described by first-principles models and nonlinear systems described by black-box models;
- Nonlinear systems with continuous control inputs and nonlinear systems with quantized control inputs;
- Nonlinear systems without uncertainty and nonlinear systems with uncertainties (polyhedral description of uncertainty and stochastic description of uncertainty);
- Nonlinear systems, consisting of interconnected nonlinear sub-systems.

The proposed mp-NLP approaches are illustrated with applications to several case studies, which are taken from diverse areas such as automotive mechatronics, compressor control, combustion plant control, reactor control, pH maintaining system control, cart and spring system control, and diving computers. This monograph introduces the authors' work on model predictive control system design using extended state space and extended non-minimal state space approaches. It systematically describes model predictive control design for chemical processes, including the basic control algorithms, the extension to predictive functional control, constrained control, closed-loop system analysis, model predictive control optimization-based PID control, genetic algorithm optimization-based model predictive control, and industrial applications. Providing important insights, useful methods and practical algorithms that can be used in chemical process control and

optimization, it offers a valuable resource for researchers, scientists and engineers in the field of process system engineering and control engineering. 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. 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 (MPC) has become a widely used methodology across all engineering disciplines, yet there are few books which study this approach. Until now, no book has addressed in detail all key issues in the field including a priori stability and robust stability results. Engineers and MPC researchers now have a volume that provides a complete overview of the theory and practice of MPC as it relates to process and control engineering. *Model-Based Predictive Control, A Practical Approach*, analyzes predictive control from its base mathematical foundation, but delivers the subject matter in a readable, intuitive style. The author writes in layman's terms, avoiding jargon and using a style that relies upon personal insight into practical applications. This detailed introduction to predictive control introduces basic MPC concepts and demonstrates how they are applied in the design and control of systems, experiments, and industrial processes. The text outlines how to model, provide robustness, handle constraints, ensure feasibility, and guarantee stability. It also details options in regard to

algorithms, models, and complexity vs. performance issues. Model Predictive Control (MPC) has become a widely used methodology across all engineering disciplines, yet there are few books which study this approach. Until now, no book has addressed in detail all key issues in the field including apriori stability and robust stability results. Engineers and MPC researchers now have a volume that provides a complete overview of the theory and practice of MPC as it relates to process and control engineering. *Model-Based Predictive Control, A Practical Approach*, analyzes predictive control from its base mathematical foundation, but delivers the subject matter in a readable, intuitive style. The author writes in layman's terms, avoiding jargon and using a style that relies upon personal insight into practical applications. This detailed introduction to predictive control introduces basic MPC concepts and demonstrates how they are applied in the design and control of systems, experiments, and industrial processes. The text outlines how to model, provide robustness, handle constraints, ensure feasibility, and guarantee stability. It also details options in regard to algorithms, models, and complexity vs. performance issues. 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. This project thesis provides a brief overview of Model Predictive Control (MPC). A brief history of industrial model predictive control technology has been presented first followed by a some concepts like the receding horizon, moves etc. which form the basis of the MPC. It follows the Optimization problem which

ultimately leads to the description of the Dynamic Matrix Control (DMC). The MPC presented in this report is based on DMC. After this the application summary and the limitations of the existing technology has been discussed and the next generation MPC, with an emphasis on potential business and research opportunities has been reviewed. Finally in the last part we generate Matlab code to implement basic model predictive controller and introduce noise into the model. We have also taken up some case studies like Swimming pool water temperature control and helicopter flight control etc. by applying the MPC controller on these models. A typical design procedure for model predictive control or control performance monitoring consists of: 1. identification of a parametric or nonparametric model; 2. derivation of the output predictor from the model; 3. design of the control law or calculation of performance indices according to the predictor. Both design problems need an explicit model form and both require this three-step design procedure. Can this design procedure be simplified? Can an explicit model be avoided? With these questions in mind, the authors eliminate the first and second step of the above design procedure, a “data-driven” approach in the sense that no traditional parametric models are used; hence, the intermediate subspace matrices, which are obtained from the process data and otherwise identified as a first step in the subspace identification methods, are used directly for the designs. Without using an explicit model, the design procedure is simplified and the modelling error caused by parameterization is eliminated. A comprehensive examination of DMPC theory and its technological applications • A comprehensive examination of DMPC theory and its technological applications from basic through to advanced level • A systematic introduction to DMPC technology providing classic DMPC coordination strategies, analysis of their performance, and design methods for both unconstrained and constrained systems • Includes the system partition methods, coordination strategies, the performance analysis and how to design

stabilized DMPC under different coordination strategies • Presents useful theories and technologies which can be used in many different industrial fields, such as the metallurgical process and high speed transport, helping readers to grasp the procedure of using the DMPC • Reflects the authors' combined research in the area, providing a wealth of and current and background information 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. Modern Predictive Control explains how MPC differs from other control methods in its implementation of a control action. Most importantly, MPC provides the flexibility to act while

optimizing—which is essential to the solution of many engineering problems in complex plants, where exact modeling is impossible. The superiority of MPC is in its numerical solution. Usually, MPC is employed to solve a finite-horizon optimal control problem at each sampling instant and obtain control actions for both the present time and a future period. However, only the current control move is applied to the plant. This complete, step-by-step exploration of various approaches to MPC: Introduces basic concepts of systems, modeling, and predictive control, detailing development from classical MPC to synthesis approaches Explores use of Model Algorithmic Control (MAC), Dynamic Matrix Control (DMC), Generalized Predictive Control (GPC), and Two-Step Model Predictive Control Identifies important general approaches to synthesis Discusses open-loop and closed-loop optimization in synthesis approaches Covers output feedback synthesis approaches with and without a finite switching horizon This book gives researchers a variety of models for use with one- and two-step control. The author clearly explains the variations between predictive control methods—and the root of these differences—to illustrate that there is no one ideal MPC and that one should remain open to selecting the best possible model in each unique circumstance. This book focuses on distributed and economic Model Predictive Control (MPC) with applications in different fields. MPC is one of the most successful advanced control methodologies due to the simplicity of the basic idea (measure the current state, predict and optimize the future behavior of the plant to determine an input signal, and repeat this procedure ad infinitum) and its capability to deal with constrained nonlinear multi-input multi-output systems. While the basic idea is simple, the rigorous analysis of the MPC closed loop can be quite involved. Here, distributed means that either the computation is distributed to meet real-time requirements for (very) large-scale systems or that distributed agents act autonomously while being coupled via the constraints and/or the

control objective. In the latter case, communication is necessary to maintain feasibility or to recover system-wide optimal performance. The term economic refers to general control tasks and, thus, goes beyond the typically predominant control objective of set-point stabilization. Here, recently developed concepts like (strict) dissipativity of optimal control problems or turnpike properties play a crucial role. The book collects research and survey articles on recent ideas and it provides perspectives on current trends in nonlinear model predictive control. Indeed, the book is the outcome of a series of six workshops funded by the German Research Foundation (DFG) involving early-stage career scientists from different countries and from leading European industry stakeholders.

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 ToolboxTM 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 eine Übersicht 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 ToolboxTM 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.

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The second edition of "Model Predictive Control" provides a thorough introduction to theoretical and practical aspects of the most commonly used MPC strategies. It bridges the gap between the powerful but often abstract techniques of control researchers and the more empirical approach of practitioners. The book demonstrates that a powerful technique does not always require complex control algorithms. Many new exercises and examples have also been added throughout. Solutions available for download from the authors' website save the tutor time and enable the student to follow results more closely even when the tutor isn't present.

Practical Design and Application of Model Predictive Control is a self-learning resource on how to design, tune and deploy an MPC using MATLAB® and Simulink®. This reference is one of the most detailed publications on how to design and tune MPC controllers. Examples presented range from double-Mass spring system, ship heading and speed control, robustness analysis through Monte-Carlo simulations, photovoltaic optimal control, and

energy management of power-split and air-handling control. Readers will also learn how to embed the designed MPC controller in a real-time platform such as Arduino®. The selected problems are nonlinear and challenging, and thus serve as an excellent experimental, dynamic system to show the reader the capability of MPC. The step-by-step solutions of the problems are thoroughly documented to allow the reader to easily replicate the results. Furthermore, the MATLAB® and Simulink® codes for the solutions are available for free download. Readers can connect with the authors through the dedicated website which includes additional free resources at www.practicalmpc.com. Illustrates how to design, tune and deploy MPC for projects in a quick manner Demonstrates a variety of applications that are solved using MATLAB® and Simulink® Bridges the gap in providing a number of realistic problems with very hands-on training Provides MATLAB® and Simulink® code solutions. This includes nonlinear plant models that the reader can use for other projects and research work Presents application problems with solutions to help reinforce the information learned 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. Nonlinear Model Predictive Control is a thorough and rigorous introduction to nonlinear model predictive control (NMPC) for discrete-time and sampled-data systems. NMPC is interpreted as an approximation of infinite-horizon optimal control so that important properties like closed-loop stability, inverse optimality and suboptimality can be derived in a uniform manner. These results are complemented by discussions of feasibility and robustness. NMPC schemes with and without stabilizing terminal constraints are detailed and intuitive examples illustrate the performance of different NMPC variants. An introduction to nonlinear optimal control algorithms gives insight into how the nonlinear optimisation routine – the core of any NMPC controller – works. An appendix covering NMPC software and accompanying software in MATLAB® and C++(downloadable from www.springer.com/ISBN) enables readers to perform computer experiments exploring the possibilities and limitations of NMPC.

Model Predictive Control (MPC) refers to a class of control algorithms in which a dynamic process model is used to predict and optimize process performance. From lower request of modeling accuracy and robustness to complicated process plants, MPC has been widely accepted in many practical fields. As the guide for researchers and engineers all over the world concerned with the latest developments of MPC, the purpose of "Advanced Model Predictive Control" is to show the readers the recent achievements in this area. The first part of this exciting book will help you comprehend the frontiers in theoretical research of MPC, such as Fast MPC, Nonlinear MPC, Distributed MPC, Multi-Dimensional MPC and Fuzzy-Neural MPC. In the second part, several excellent applications of MPC in modern industry are proposed and efficient commercial software for MPC is introduced. Because of its special industrial origin, we believe that MPC will remain energetic in the future. Model Predictive Control for Doubly-Fed Induction Generators and Three-Phase Power Converters describes the application of model predictive control techniques with modulator and finite control sets to squirrel cage induction motor and in doubly-fed induction generators using field orientation control techniques as both current control and direct power control. Sections discuss induction machines, their key modulation techniques, introduce the utility of model predictive control, review core concepts of vector control, direct torque control, and direct power control alongside novel approaches of MPC. Mathematical modeling of cited systems, MPC theory, their applications, MPC design and simulation in MATLAB are also considered in-depth. The work concludes by addressing implementation considerations, including generator operation under voltage sags or distorted voltage and inverters connected to the grid operating under distorted voltage. Experimental results are presented in full. Adopts model predictive control design for optimized induction machines geared for complex grid dynamics Demonstrates how to simulate model

predictive control using MATLAB and Simulink Presents information about hardware implementation to obtain experimental results Covers generator operation under voltage sags or distorted voltage The past three decades have seen rapid development in the area of model predictive control with respect to both theoretical and application aspects. Over these 30 years, model predictive control for linear systems has been widely applied, especially in the area of process control. However, today's applications often require driving the process over a wide region and close to the boundaries of operability, while satisfying constraints and achieving near-optimal performance. Consequently, the application of linear control methods does not always lead to satisfactory performance, and here nonlinear methods must be employed. This is one of the reasons why nonlinear model predictive control (NMPC) has enjoyed significant attention over the past years, with a number of recent advances on both the theoretical and application frontier. Additionally, the widespread availability and steadily increasing power of today's computers, as well as the development of specially tailored numerical solution methods for NMPC, bring the practical applicability of NMPC within reach even for very fast systems. This has led to a series of new, exciting developments, along with new challenges in the area of NMPC. For the first time, a textbook that brings together classical predictive control with treatment of up-to-date robust and stochastic techniques. Model Predictive Control describes the development of tractable algorithms for uncertain, stochastic, constrained systems. The starting point is classical predictive control and the appropriate formulation of performance objectives and constraints to provide guarantees of closed-loop stability and performance. Moving on to robust predictive control, the text explains how similar guarantees may be obtained for cases in which the model describing the system dynamics is subject to additive disturbances and parametric uncertainties. Open- and closed-loop optimization are considered and the state of the art in

computationally tractable methods based on uncertainty tubes presented for systems with additive model uncertainty. Finally, the tube framework is also applied to model predictive control problems involving hard or probabilistic constraints for the cases of multiplicative and stochastic model uncertainty. The book provides: extensive use of illustrative examples; sample problems; and discussion of novel control applications such as resource allocation for sustainable development and turbine-blade control for maximized power capture with simultaneously reduced risk of turbulence-induced damage. Graduate students pursuing courses in model predictive control or more generally in advanced or process control and senior undergraduates in need of a specialized treatment will find Model Predictive Control an invaluable guide to the state of the art in this important subject. For the instructor it provides an authoritative resource for the construction of courses. Describes the general principles and current research into Model Predictive Control (MPC); the most up-to-date control method for power converters and drives The book starts with an introduction to the subject before the first chapter on classical control methods for power converters and drives. This covers classical converter control methods and classical electrical drives control methods. The next chapter on Model predictive control first looks at predictive control methods for power converters and drives and presents the basic principles of MPC. It then looks at MPC for power electronics and drives. The third chapter is on predictive control applied to power converters. It discusses: control of a three-phase inverter; control of a neutral point clamped inverter; control of an active front end rectifier, and; control of a matrix converter. In the middle of the book there is Chapter four - Predictive control applied to motor drives. This section analyses predictive torque control of industrial machines and predictive control of permanent magnet synchronous motors. Design and implementation issues of model predictive control is the subject of the final chapter. The following topics are

described in detail: cost function selection; weighting factors design; delay compensation; effect of model errors, and prediction of future references. While there are hundreds of books teaching control of electrical energy using pulse width modulation, this will be the very first book published in this new topic. Unique in presenting a completely new theoretic solution to control electric power in a simple way Discusses the application of predictive control in motor drives, with several examples and case studies Matlab is included on a complementary website so the reader can run their own simulations

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