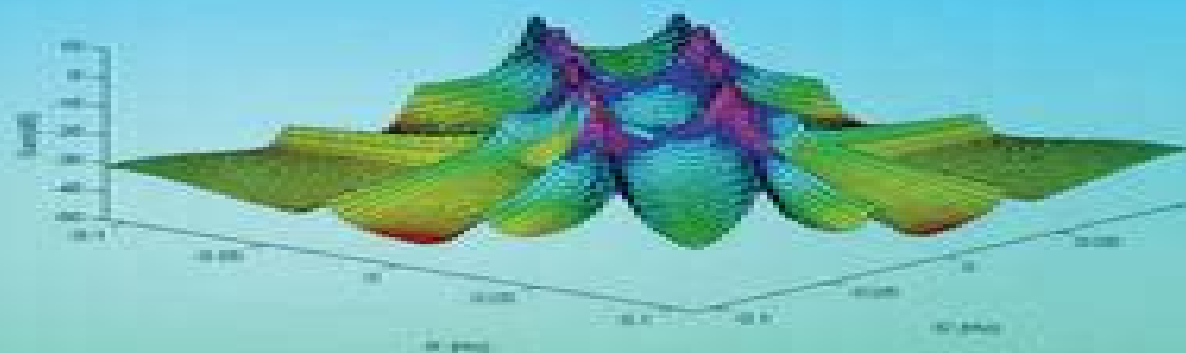# Nonlinear System Identification

NARMAX Methods
in the Time, Frequency,
and Spatio-Temporal Domains

Stephen A Billings

WILEY

Nonlinear System Identification

Julius S. Bendat

Nonlinear System Identification:

Nonlinear system identification. 2. Nonlinear system structure identification Robert Haber,László Keviczky,1999 This is the second part of a two volume handbook presenting a comprehensive overview of nonlinear dynamic system identification The books include many aspects of nonlinear processes such as modelling parameter estimation structure search nonlinearity and model validity tests Nonlinear System Identification Oliver Nelles,2013-03-09 Written from an engineering point of view this book covers the most common and important approaches for the identification of nonlinear static and dynamic systems The book also provides the reader with the necessary background on optimization techniques making it fully self contained The new edition includes exercises **Block-oriented Nonlinear System Identification** Fouad Giri,Er-Wei Bai,2010-08-18 Block oriented Nonlinear System Identification deals with an area of research that has been very active since the turn of the millennium The book makes a pedagogical and cohesive presentation of the methods developed in that time These include iterative and over parameterization techniques stochastic and frequency approaches support vector machine subspace and separable least squares methods blind identification method bounded error method and decoupling inputs approach The identification methods are presented by authors who have either invented them or contributed significantly to their development All the important issues e g input design persistent excitation and consistency analysis are discussed The practical relevance of block oriented models is illustrated through biomedical physiological system modelling The book will be of major interest to all those who are concerned with nonlinear system identification whatever their activity areas This is particularly the case for educators in electrical mechanical chemical and biomedical engineering and for practising engineers in process aeronautic aerospace robotics and vehicles control Block oriented Nonlinear System Identification serves as a reference for active researchers new comers industrial and education practitioners and graduate students alike **Nonlinear System Identification — Input-Output Modeling Approach** Robert Haber,L. Keviczky,2013-09-14 The subject of the book is to present the modeling parameter estimation and other aspects of the identification of nonlinear dynamic systems The treatment is restricted to the input output modeling approach Because of the widespread usage of digital computers discrete time methods are preferred Time domain parameter estimation methods are dealt with in detail frequency domain and power spectrum procedures are described shortly The theory is presented from the engineering point of view and a large number of examples of case studies on the modeling and identifications of real processes illustrate the methods Almost all processes are nonlinear if they are considered not merely in a small vicinity of the working point To exploit industrial equipment as much as possible mathematical models are needed which describe the global nonlinear behavior of the process If the process is unknown or if the describing equations are too complex the structure and the parameters can be determined experimentally which is the task of identification The book is divided into seven chapters dealing with the following topics 1 Nonlinear dynamic process models 2 Test signals for identification 3

Parameter estimation methods 4 Nonlinearity test methods 5 Structure identification 6 Model validity tests 7 Case studies on identification of real processes Chapter I summarizes the different model descriptions of nonlinear dynamical systems

Adaptive Nonlinear System Identification Tokunbo Ogunfunmi,2008-11-01 Focuses on System Identification applications of the adaptive methods presented but which can also be applied to other applications of adaptive nonlinear processes Covers recent research results in the area of adaptive nonlinear system identification from the authors and other researchers in the field **Adaptive Nonlinear System Identification** Tokunbo Ogunfunmi,2007-09-05 Focuses on System Identification applications of the adaptive methods presented but which can also be applied to other applications of adaptive nonlinear processes Covers recent research results in the area of adaptive nonlinear system identification from the authors and other researchers in the field *Nonlinear System Identification* Oliver Nelles,2001 Written from an engineering point of view this book covers the most common and important approaches for the identification of nonlinear static and dynamic systems The book also provides the reader with the necessary background on optimization techniques making it fully self contained The new edition includes exercises *Identification of Dynamic Systems* Rolf Isermann,Marco Münchhof,2010-11-22 Precise dynamic models of processes are required for many applications ranging from control engineering to the natural sciences and economics Frequently such precise models cannot be derived using theoretical considerations alone Therefore they must be determined experimentally This book treats the determination of dynamic models based on measurements taken at the process which is known as system identification or process identification Both offline and online methods are presented i e methods that post process the measured data as well as methods that provide models during the measurement The book is theory oriented and application oriented and most methods covered have been used successfully in practical applications for many different processes Illustrative examples in this book with real measured data range from hydraulic and electric actuators up to combustion engines Real experimental data is also provided on the Springer webpage allowing readers to gather their first experience with the methods presented in this book Among others the book covers the following subjects determination of the non parametric frequency response fast Fourier transform correlation analysis parameter estimation with a focus on the method of Least Squares and modifications identification of time variant processes identification in closed loop identification of continuous time processes and subspace methods Some methods for nonlinear system identification are also considered such as the Extended Kalman filter and neural networks The different methods are compared by using a real three mass oscillator process a model of a drive train For many identification methods hints for the practical implementation and application are provided The book is intended to meet the needs of students and practicing engineers working in research and development design and manufacturing **Nonlinear System Identification** Oliver Nelles,2020-09-09 This book provides engineers and scientists in academia and industry with a thorough understanding of the underlying principles of nonlinear system identification It equips them to apply the models

and methods discussed to real problems with confidence while also making them aware of potential difficulties that may arise in practice Moreover the book is self contained requiring only a basic grasp of matrix algebra signals and systems and statistics Accordingly it can also serve as an introduction to linear system identification and provides a practical overview of the major optimization methods used in engineering The focus is on gaining an intuitive understanding of the subject and the practical application of the techniques discussed The book is not written in a theorem proof style instead the mathematics is kept to a minimum and the ideas covered are illustrated with numerous figures examples and real world applications In the past nonlinear system identification was a field characterized by a variety of ad hoc approaches each applicable only to a very limited class of systems With the advent of neural networks fuzzy models Gaussian process models and modern structure optimization techniques a much broader class of systems can now be handled Although one major aspect of nonlinear systems is that virtually every one is unique tools have since been developed that allow each approach to be applied to a wide variety of systems   **Nonlinear System Identification Study. Part I. Implementation Feasibility Study** E. J. Ewen,GENERAL ELECTRIC CO UTICA N Y AIRCRAFT EQUIPMENT DIV.,1979 The implementation feasibility of a nonlinear system identification technique is evaluated in this report The identification technique uses a black box approach requiring measurements only at system input and output terminals and is applicable to weakly nonlinear systems whose behavior is adequately characterized by a finite Volterra series Three hardware implementations of the identification technique are postulated and their respective performances are evaluated The impact of A D converter quantization error non ideal amplifiers multipliers and integrators on performance of the identification process is assessed Performance requirements for each of the three implementations are derived via simulation and analysis The feasibility of implementing the technique using commercially available state of the art components and measurement equipment in each implementation is assessed RADC TR 79 199 Part II A computational complexity study of the identification technique processing to determine the class of nonlinear systems to which the technique can be practically applied will be published at a later date Author   Nonlinear System Identification Stephen A. Billings,2013-07-29 Nonlinear System Identification NARMAX Methods in the Time Frequency and Spatio Temporal Domains describes a comprehensive framework for the identification and analysis of nonlinear dynamic systems in the time frequency and spatio temporal domains This book is written with an emphasis on making the algorithms accessible so that they can be applied and used in practice Includes coverage of The NARMAX nonlinear autoregressive moving average with exogenous inputs model The orthogonal least squares algorithm that allows models to be built term by term where the error reduction ratio reveals the percentage contribution of each model term Statistical and qualitative model validation methods that can be applied to any model class Generalised frequency response functions which provide significant insight into nonlinear behaviours A completely new class of filters that can move split spread and focus energy The response spectrum map and the study of sub harmonic and severely nonlinear systems

Algorithms that can track rapid time variation in both linear and nonlinear systems The important class of spatio temporal systems that evolve over both space and time Many case study examples from modelling space weather through identification of a model of the visual processing system of fruit flies to tracking causality in EEG data are all included to demonstrate how easily the methods can be applied in practice and to show the insight that the algorithms reveal even for complex systems NARMAX algorithms provide a fundamentally different approach to nonlinear system identification and signal processing for nonlinear systems NARMAX methods provide models that are transparent which can easily be analysed and which can be used to solve real problems This book is intended for graduates postgraduates and researchers in the sciences and engineering and also for users from other fields who have collected data and who wish to identify models to help to understand the dynamics of their systems **Nonlinear system identification. 1. Nonlinear system parameter identification** Robert Haber,László Keviczky,1999 The first of two volumes this handbook presents a comprehensive overview of nonlinear dynamic system parameter identification The volumes cover many aspects of nonlinear processes including modelling parameter estimation structure search nonlinearity and model validity tests **System Identification for Structured Nonlinear Systems** Mareike Silke Claassen,2001 Nonlinear system identification : a state-space approach Vincent Verdult,2002 *Nonlinear System Identification by Haar Wavelets* Przemysław Sliwinski,2012-10-12 In order to precisely model real life systems or man made devices both nonlinear and dynamic properties need to be taken into account The generic black box model based on Volterra and Wiener series is capable of representing fairly complicated nonlinear and dynamic interactions however the resulting identification algorithms are impractical mainly due to their computational complexity One of the alternatives offering fast identification algorithms is the block oriented approach in which systems of relatively simple structures are considered The book provides nonparametric identification algorithms designed for such systems together with the description of their asymptotic and computational properties *Nonlinear System Analysis and Identification from Random Data* Julius S. Bendat,1990-03-16 Describes procedures to identify and analyze the properties of many types of nonlinear systems from random data measured at the input and output points of physical systems Improvements are offered in applying older techniques and problems that traditionally have been difficult to analyze are solved by new simpler procedures Formulas are stated for optimum nonlinear system identification in both general models consisting of parallel linear bilinear and trilinear systems and special models consisting of parallel linear finite memory square law systems and finite memory cubic systems New results obtained here show when and how to replace complicated single input output nonlinear models with simpler alternative multiple input single output linear models New error analysis formulas are presented to design experiments and to evaluate estimates obtained from measured data Includes many illustrative examples **An Intelligent Nonlinear System Identification Method with an Application to Condition Monitoring** Clara Echavarria,2015 Neural networks are black box model structures that map inputs to outputs

and do not require underlying mathematical models between the two They are frequently used in the field of system identification the area that deals with the development of system models based on input output data In this work a hybrid system identification method is implemented with neural networks NN and the Minimum Model Error estimator MME on different benchmark experimental setups as well as simulations The MME algorithm uses a cost function with a covariance constraint to determine smooth state estimates of a system given noisy measurement data and an assumed model As a byproduct it generates a vector of unmodeled nonlinear or linear system dynamics which can then be modeled by a neural network Combining this neural network with the assumed model from MME a system plant model is obtained The purpose of neural networks in this research is two fold to demonstrate the advantages of combined MME NN models over some common system identification methods and to investigate the feasibility of using the data stored in the network structure of those models to develop a classification scheme for condition monitoring The approach to classification that is used in this research does not lead to successful implementation of such a scheme Abstract   **Block-oriented Nonlinear System Identification Using Semidenite Programming** Younghee Han,2012 Identification of block oriented nonlinear systems has been an active research area for the last several decades A block oriented nonlinear system represents a nonlinear dynamical system as a combination of linear dynamic systems and static nonlinear blocks In block oriented nonlinear systems each block linear dynamic systems and static nonlinearity can be connected in many different ways series parallel feedback and this flexibility provides the block oriented modeling approach with an ability to capture a large class of nonlinear systems However intermediate signals in such block oriented systems are not measurable and the inaccessibility of such measurements is the main difficulty in block oriented nonlinear system identification Recently a system identification method using rank minimization has been introduced for linear system identification Finding the simplest model within a feasible model set restricted by convex constraints can often be formulated as a rank minimization problem In this research the rank minimization approach is extended to block oriented nonlinear system identification The system parameter estimation problem is formulated as a rank minimization problem or the combination of prediction error and rank minimization problems by constraining a finite dimensional time dependency of a linear dynamic system and by using the monotonicity of static nonlinearity This allows us to reconstruct non measurable intermediate signals and once the intermediate signals have been reconstructed the identification of each block can be solved with the standard Prediction Error method or Least Squares method The research work presented in this dissertation proposes a new approach for block oriented system identification by tackling the inaccessibility of measurement of intermediate signals in block oriented nonlinear systems via rank minimization Since the rank minimization problem is non convex the rank minimization problem is relaxed to a semidefinite programming problem by minimizing the nuclear norm instead of the rank The research contributes to advances in block oriented nonlinear system identification   **Nonlinear System Identification Study. Part 2. Computational**

Complexity Study E. J. Ewen,GENERAL ELECTRIC CO UTICA NY AEROSPACEELECTRONIC SYSTEMS Dept,1980 The computational complexity of a nonlinear system identification technique is evaluated in this report The identification technique uses a black box approach requiring measurements only at system input and output terminals and is applicable to weakly nonlinear systems whose behavior is adequately characterized by a finite Volterra Series The computational aspects of the technique are evaluated in terms of the complexity of the calculations and the complexity of the system being implemented Techniques for reducing the order of the second order response are investigated These techniques include restricted frequency range integration time control and dominant pole concepts The class of systems to which the technique can be applied is evaluated   **System Identification With Matlab** A. Smith,2017-11-19 This book develops the work with Nonlinear Models and Time Series Identification To represent nonlinear system dynamics you can estimate Hammerstein Weiner models and nonlinear ARX models with wavelet network tree partition and sigmoid network nonlinearities MATLAB System Identification Toolbox performs grey box system identification for estimating parameters of a user defined model You can use the identified model for system response prediction and plant modeling in Simulink The toolbox also supports time series data modeling and time series forecasting It is possible to analyze time series data by identifying linear and nonlinear models including AR ARMA and state space models forecast values The most important content that this book provides are the following When to Fit Nonlinear Models Nonlinear Model Estimation Nonlinear Model Structures Nonlinear ARX Models Hammerstein Wiener Models Nonlinear Grey Box Models Preparing Data for Nonlinear Identification Identifying Nonlinear ARX Models Prepare Data for Identification Configure Nonlinear ARX Model Structure Specify Estimation Options for Nonlinear ARX Models Initialize Nonlinear ARX Estimation Using Linear Model Estimate Nonlinear ARX Models in the App Estimate Nonlinear ARX Models at the Command Line Estimate Nonlinear ARX Models Initialized Using Linear ARX Models Validate Nonlinear ARX Models Using Nonlinear ARX Models Linear Approximation of Nonlinear Black Box Models Nonlinear Black Box Model Identification Identifying Hammerstein Wiener Models Available Nonlinearity Estimators for Hammerstein Wiener Models Estimate Hammerstein Wiener Models in the App Estimate Hammerstein Wiener Models at the Command Line Validating Hammerstein Wiener Models How the Software Computes Hammerstein Wiener Model Output Evaluating Nonlinearities SISO Evaluating Nonlinearities MIMO Simulation of Hammerstein Wiener Model Estimate Hammerstein Wiener Models Initialized Using Linear OE Models Estimate Linear Grey Box Models Estimate Continuous Time Grey Box Model for Heat Diffusion Estimate Discrete Time Grey Box Model with Parameterized Disturbance Estimate Coefficients of ODEs to Fit Given Solution Estimate Model Using Zero Pole Gain Parameters Estimate Nonlinear Grey Box Models Identifying State Space Models with Separate Process and Measurement Noise Descriptions Time Series Identification Preparing Time Series Data Estimate Time Series Power Spectra Estimate AR and ARMA Models Definition of AR and ARMA Models Estimating Polynomial Time Series Models in the App Estimating AR and ARMA Models at the Command Line

Estimate State Space Time Series Models Identify Time Series Models at the Command Line Estimate ARIMA Models Analyze Time Series Models Introduction to Forecasting of Dynamic System Response Forecasting Time Series Using Linear Models Forecasting Response of Linear Models with Exogenous Inputs Forecasting Response of Nonlinear Models Forecast the Output of a Dynamic System Forecast Time Series Data Using an ARMA Model Recursive Model Identification

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