Fermentation Process Modeling Using Takagi-Sugeno Fuzzy Model

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Abstract: Fermentation process is vital and important in many biotechnological applications. However modeling the fermentation process is considered a challenging and complex problem. The complexity of the problem is driven by the need of efficient, accurate, not expensive, and reliable predictive models. In this paper, we apply a Takagi-Sugeno Fuzzy Logic technique for modeling the lipase activity production based on nutritional and physico-chemical factors to estimate the lipase activities. The accuracy of the developed fuzzy model is measured, validated and compared with both the multiple regression and artificial neural network models. The fuzzy model successfully showed competitive and promising modeling results.

Key–Words: Fermentation process, Lipase activity production, Takagi-Sugeno Fuzzy Modele.

1 Introduction

Lipase production is getting more and more attention in the industry and business field recently due to their biotechnological applications [1]. Lipases have a wide range of uses in industry productions such as diary-based products, detergents, drugs, cosmetics and leather processes [2]. On the other side, Lipase production is a challenging, complex and not easy to model or monitor [2]. The complexity is due to the nature of lipase production which is highly dependent on its operating conditions that affect its growth. These operating conditions include nutritional and physico-chemical factors such as temperature, initial pH, incubation period, time, inoculum size and agitation rate [1–3]. Consequently, deciding upon an optimization method and choosing a modeling technique are vital issues in the process of producing reliable lipase products with high standards. Efficient optimization and modeling can dramatically improve the systems performance and reduce the costs [3].

In biologyical research, response surface methodology (RSM) is one of the most applied methods in modeling the biological processes. RSM is a statistical and mathematical based system for modeling and optimizing complex processes. RSM explores the relationships between the response (output variable) and the independent variables (input variables). RSM has many advantages such as it reflects the significance of the input variables, alone or in combination, in a given model. Moreover, it reduces the cost of analysis by minimizing the number of experimental trials needed to evaluate input variables and their interactions [4]. Though, RSA is not applicable in all biological applications [3].

In many cases, output results are out of expectations when modeling and predicting systems based on mathematical equations are used for controlling the interactions between the input variables in the process for lipase fermentation. Therefore, a considerable number of previous studies employed empirical models based on artificial intelligence and machine learning approaches. By the following paragraphs we give an insight into some important studies in the field.

Among artificial intelligence and machine learning approaches, Artificial Neural Networks (ANNs) are the most applied in lipase modeling and prediction. In [3] authors used the best composition of production medium among the best previously published media, then they made a comparison by applying both RSM and ANN for optimizing the physical factors for extracellular thermostable lipase production. Although both techniques gave good predictions, the ANN showed better performance in data fitting and estimation capabilities. However ANN in general suffers some disadvantages; ANNs relatively need large amounts of data for training and they work as black input/output box, it is hard to interpret their results.

In [5] ANN model, based on feed forward architecture and back propagation as training algorithm was applied to predict the state of batch fermentations with grape juice extracted from grape waste. The Levenberg- Marquardt optimization technique has been used to upgrade the network by minimizing the sum square error (SSE). Authors found that the best performance of the model for predicting cell

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Gorazd Karer,Igor Škrjanc

Fermentation Process Modeling Using Takagi Sugeno Fuzzy Model:

Fuzzy Decision Making In Modeling And Control Joao M Costa Sousa,Uzay Kaymak,2002-12-03 Decision making and control are two fields with distinct methods for solving problems and yet they are closely related This book bridges the gap between decision making and control in the field of fuzzy decisions and fuzzy control and discusses various ways in which fuzzy decision making methods can be applied to systems modeling and control Fuzzy decision making is a powerful paradigm for dealing with human expert knowledge when one is designing fuzzy model based controllers The combination of fuzzy decision making and fuzzy control in this book can lead to novel control schemes that improve the existing controllers in various ways The following applications of fuzzy decision making methods for designing control systems are considered Fuzzy decision making for enhancing fuzzy modeling The values of important parameters in fuzzy modeling algorithms are selected by using fuzzy decision making Fuzzy decision making for designing signal based fuzzy controllers The controller mappings and the defuzzification steps can be obtained by decision making methods Fuzzy design and performance specifications in model based control Fuzzy constraints and fuzzy goals are used Design of model based controllers combined with fuzzy decision modules Human operator experience is incorporated for the performance specification in model based control The advantages of bringing together fuzzy control and fuzzy decision making are shown with multiple examples from real and simulated control systems **Instrument Engineers' Handbook, Volume Two** Bela G. Liptak,2018-10-08 The latest update to Bela Liptak s acclaimed bible of instrument engineering is now available Retaining the format that made the previous editions bestsellers in their own right the fourth edition of Process Control and Optimization continues the tradition of providing quick and easy access to highly practical information The authors are practicing engineers not theoretical people from academia and their from the trenches advice has been repeatedly tested in real life applications Expanded coverage includes descriptions of overseas manufacturer s products and concepts model based optimization in control theory new major inventions and innovations in control valves and a full chapter devoted to safety With more than 2000 graphs figures and tables this all inclusive encyclopedic volume replaces an entire library with one authoritative reference The fourth edition brings the content of the previous editions completely up to date incorporates the developments of the last decade and broadens the horizons of the work from an American to a global perspective B la G Lipt k speaks on Post Oil Energy Technology on the AT T Tech Channel *Multiple Model Approaches To Nonlinear Modelling And Control* R Murray-Smith,T. Johansen,2020-11-25 This work presents approaches to modelling and control problems arising from conditions of ever increasing nonlinearity and complexity It prescribes an approach that covers a wide range of methods being combined to provide multiple model solutions Many component methods are described as well as discussion of the strategies available for building a successful multiple model approach **Predictive Approaches to Control of Complex Systems** Gorazd Karer,Igor Škrjanc,2012-09-20 A predictive control algorithm uses a model of the controlled system to

predict the system behavior for various input scenarios and determines the most appropriate inputs accordingly Predictive controllers are suitable for a wide range of systems therefore their advantages are especially evident when dealing with relatively complex systems such as nonlinear constrained hybrid multivariate systems etc However designing a predictive control strategy for a complex system is generally a difficult task because all relevant dynamical phenomena have to be considered Establishing a suitable model of the system is an essential part of predictive control design Classic modeling and identification approaches based on linear systems theory are generally inappropriate for complex systems hence models that are able to appropriately consider complex dynamical properties have to be employed in a predictive control algorithm This book first introduces some modeling frameworks which can encompass the most frequently encountered complex dynamical phenomena and are practically applicable in the proposed predictive control approaches Furthermore unsupervised learning methods that can be used for complex system identification are treated Finally several useful predictive control algorithms for complex systems are proposed and their particular advantages and drawbacks are discussed The presented modeling identification and control approaches are complemented by illustrative examples The book is aimed towards researches and postgraduate students interested in modeling identification and control as well as towards control engineers needing practically usable advanced control methods for complex systems **Intelligent Control in Drying** Alex Martynenko,Andreas Bück,2018-09-03 Despite the available general literature in intelligent control there is a definite lack of knowledge and know how in practical applications of intelligent control in drying This book fills that gap Intelligent Control in Drying serves as an innovative and practical guide for researchers and professionals in the field of drying technologies providing an overview of control principles and systems used in drying operations from classical to model based to adaptive and optimal control At the same time it lays out approaches to synthesis of control systems based on the objectives and control strategies reflecting complexity of drying process and material under drying This essential reference covers both fundamental and practical aspects of intelligent control sensor fusion and dynamic optimization with respect to drying

New Developments in Robotics Automation and Control Alex Lazinica,2008-10-01 This book represents the contributions of the top researchers in the field of robotics automation and control and will serve as a valuable tool for professionals in these interdisciplinary fields It consists of 25 chapter that introduce both basic research and advanced developments covering the topics such as kinematics dynamic analysis accuracy optimization design modelling simulation and control Without a doubt the book covers a great deal of recent research and as such it works as a valuable source for researchers interested in the involved subjects Handbook of Food and Bioprocess Modeling Techniques Shyam S. Sablani,Ashim K. Datta,M. Shafiur Rahman,Arun S. Mujumdar,2006-12-19 With the advancement of computers the use of modeling to reduce time and expense and improve process optimization predictive capability process automation and control possibilities is now an integral part of food science and engineering New technology and ease of use expands the range of techniques that

scientists and researchers have at the **Advances in Process Control with Real Applications** Ch. Venkateswarlu,2025-06-18 Advances in Process Control with Real Applications presents various advanced controllers including the formulation design and implementation of various advanced control strategies for a wide variety of processes These strategies include generalized predictive control with and without constraints linear and nonlinear model predictive control dynamic matrix control nonlinear control such as generic model control globally linearizing control and nonlinear internal model control optimal and optimizing control inferential control intelligent control based on fuzzy reasoning and neural networks and controllers based on stochastic and evolutionary optimization This book will be highly beneficial to students researchers and industry professionals working in process design process monitoring process systems engineering process operations and control and related areas Describes various advanced controllers for the control of complex nonlinear processes Provides the fundamentals algorithms approaches control strategies and implementation procedures systematically Highlights the significance and importance of advanced process control with many real applications

Type-2 Fuzzy Logic Rómulo Antão,2017-07-23 This book focuses on a particular domain of Type 2 Fuzzy Logic related to process modeling and control applications It deepens readers understanding of Type 2 Fuzzy Logic with regard to the following three topics using simpler methods to train a Type 2 Takagi Sugeno Fuzzy Model using the principles of Type 2 Fuzzy Logic to reduce the influence of modeling uncertainties on a locally linear n step ahead predictor and developing model based control algorithms according to the Generalized Predictive Control principles using Type 2 Fuzzy Sets Throughout the book theory is always complemented with practical applications and readers are invited to take their learning process one step farther and implement their own applications using the algorithms source codes provided As such the book offers avaluable referenceguide for allengineers and researchers in the field ofcomputer science who are interested in intelligent systems rule based systems and modeling uncertainty **Intelligent Engineering Systems and Computational Cybernetics** J.A. Tenreiro Machado,Béla Pátkai,Imre J. Rudas,2008-12-18 Engineering practice often has to deal with complex systems of multiple variable and multiple parameter models almost always with strong non linear coupling The conventional analytical techniques based approaches for describing and predicting the behaviour of such systems in many cases are doomed to failure from the outset even in the phase of the construction of a more or less appropriate mathematical model These approaches normally are too categorical in the sense that in the name of modelling accuracy they try to describe all the structural details of the real physical system to be modelled This can significantly increase the intricacy of the model and may result in a enormous computational burden without achieving considerable improvement of the solution The best paradigm exemplifying this situation may be the classic perturbation theory the less significant the achievable correction the more work has to be invested to obtain it A further important component of machine intelligence is a kind of structural uniformity giving room and possibility to model arbitrary particular details a priori not specified and

unknown This idea is similar to the ready to wear industry which introduced products which can be slightly modified later on in contrast to tailor made creations aiming at maximum accuracy from the beginning These subsequent corrections can be carried out by machines automatically This learning ability is a key element of machine intelligence The past decade confirmed that the view of typical components of the present soft computing as fuzzy logic neural computing evolutionary computation and probabilistic reasoning are of complementary nature and that the best results can be applied by their combined application Today the two complementary branches of Machine Intelligence that is Artificial Intelligence and Computational Intelligence serve as the basis of Intelligent Engineering Systems Thehuge number of scientific results published in Journal and conference proceedings worldwide substantiates this statement The present book contains several articles taking different viewpoints in the field of intelligent systems *Non-linear Predictive Control* Basil Kouvaritakis,Mark Cannon,2001-10-26 The advantage of model predictive control is that it can take systematic account of constraints thereby allowing processes to operate at the limits of achievable performance Engineers in academia industry and government from the US and Europe explain how the linear version can be adapted and applied to the nonlinear conditions that characterize the dynamics of most real manufacturing plants They survey theoretical and practical trends describe some specific theories and demonstrate their practical application derive strategies that provide appropriate assurance of closed loop stability and discuss practical implementation Annotation copyrighted by Book News Inc Portland OR **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 Readings in Fuzzy Sets for Intelligent Systems Didier J. Dubois,Henri Prade,Ronald R. Yager,2014-05-12 Readings in Fuzzy Sets for Intelligent Systems

is a collection of readings that explore the main facets of fuzzy sets and possibility theory and their use in intelligent systems Basic notions in fuzzy set theory are discussed along with fuzzy control and approximate reasoning Uncertainty and informativeness information processing and membership cognition neural networks and learning are also considered Comprised of eight chapters this book begins with a historical background on fuzzy sets and possibility theory citing some forerunners who discussed ideas or formal definitions very close to the basic notions introduced by Lotfi Zadeh 1978 The reader is then introduced to fundamental concepts in fuzzy set theory including symmetric summation and the setting of fuzzy logic uncertainty and informativeness and fuzzy control Subsequent chapters deal with approximate reasoning information processing decision and management sciences and membership cognition neural networks and learning Numerical methods for fuzzy clustering are described and adaptive inference in fuzzy knowledge networks is analyzed This monograph will be of interest to both students and practitioners in the fields of computer science information science applied mathematics and artificial intelligence Microbial products for future industrialization Angana Sarkar,Idris Adewale Ahmed,2023-10-11 This book Microbial Products for Future Industrialization focuses on the exploitation of various advanced microbial and molecular biology technologies and their associated processes especially the microbial molecular chemical nexus for the future industrialization of emerging new microbial products The descriptions given in its chapters take the reader through an entire journey of new emerging microbial products from lab to industry and provide new information that has not yet been fully exploited for future industrialization steps This volume is a great resource for readers seeking a more comprehensive material covering the technical economic and societal aspects that impact bioprocessing of microbial products at the industrial level along with biotechnological intervention for better production of microbial products in near future This book also encompasses advanced and updated information as well as future directions for young researchers and scientists and academics who are working in the field of microbial product production related to sustainability

Measurement, Monitoring, Modelling and Control of Bioprocesses Carl-Fredrik Mandenius,Nigel J Titchener-Hooker,2014-07-08 Automated Measurement and Monitoring of Bioprocesses Key Elements of the M3C Strategy by Bernhard Sonnleitner Automatic Control of Bioprocesses by Marc Stanke Bernd Hitzmann An Advanced Monitoring Platform for Rational Design of Recombinant Processes by G Striedner K Bayer Modelling Approaches for Bio Manufacturing Operations by Sunil Chhatre Extreme Scale Down Approaches for Rapid Chromatography Column Design and Scale Up During Bioprocess Development by Sunil Chhatre Applying Mechanistic Models in Bioprocess Development by Rita Lencastre Fernandes Vijaya Krishna Bodla Magnus Carlquist Anna Lena Heins Anna Eliasson Lantz G rkan Sin and Krist V Gernaey Multivariate Data Analysis for Advancing the Interpretation of Bioprocess Measurement and Monitoring Data by Jarka Glassey Design of Pathway Level Bioprocess Monitoring and Control Strategies Supported by Metabolic Networks by In s A Isidro Ana R Ferreira Jo o J Clemente Ant nio E Cunha Jo o M L Dias Rui Oliveira Knowledge Management and Process

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Evolving Rule-Based Models Plamen P. Angelov,2002-02-26 The idea about this book has evolved during the process of

its preparation as some of the results have been achieved in parallel with its writing One reason for this is that in this area of research results are very quickly updated Another is possibly that a strong unchallenged theoretical basis in this field still does not fully exist From other hand the rate of innovation competition and demand from different branches of industry from biotech industry to civil and building engineering from market forecasting to civil aviation from robotics to emerging e commerce is increasingly pressing for more customised solutions based on learning consumers behaviour A highly interdisciplinary and rapidly innovating field is forming which focus is the design of intelligent self adapting systems and machines It is on the crossroads of control theory artificial and computational intelligence different engineering disciplines borrowing heavily from the biology and life sciences It is often called intelligent control soft computing or intelligent technology Some other branches have appeared recently like intelligent agents which migrated from robotics to different engineering fields data fusion knowledge extraction etc which are inherently related to this field The core is the attempts to enhance the abilities of the classical control theory in order to have more adequate flexible and adaptive models and control algorithms **Mathematical Modelling and Scientific Computation** P. Balasubramaniam,R Uthayakumar,2012-03-02 This book constitutes the refereed proceedings of the International Conference on Mathematical Modelling and Scientific Intelligence ICMMSC 2012 Gandhigram Tamil Nadu India in March 2012 The 62 revised full papers presented were carefully reviewed and selected from 332 submissions The papers are organized in two topical sections on mathematical modelling and on scientific computation

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