Model Based Process Control: Proceedings Of The IFAC Workshop, Atlanta, Georgia, USA, 13-14 June 198

Preprints of the 8th IFAC Symposium on Advanced Control of Chemical Processes
The International Federation of Automatic Control
Furama Riverfront, Singapore, July 10-13, 2012

Construction of Kinetic Model Library of Metabolic Networks

Gengjie Jia*, Rudiyanto Gunawan**

** Chemical and Pharmaceutical Engineering, Singapore-MIT Alliance, 117576 Singapore (e-mail: jiagengjie@nus.edu.sg).*
*** Institute for Chemical and Bioengineering, ETH Zürich, 8093 Zürich, Switzerland (e-mail: rudi.gunawan@chem.ethz.ch).*

Abstract: Kinetic model identification of metabolic networks is important, but still represents a significant challenge. The difficulties faced vary from the vast kinetic parameter search space to the lack of complete parameter identifiability. To meet these challenges, an incremental modeling approach is proposed here, including two key components—dynamic flux calculation and flux-based kinetic parameter estimation. In essence, the identification method relies on time-course concentration data to generate the family of consistent metabolic flux values and by doing so, the parameter estimation step can be done one flux at a time. The key contribution of the method is an efficient generation of a library of kinetic models with similar goodness of fit to the provided data. The performance of this identification method is demonstrated using a generic branched metabolic pathway model and the glycolytic pathway model of *Lactococcus lactis (L. lactis)*.

Keywords: Library Construction, Dynamic Flux Calculation, Parameter Regression, Metabolic Kinetic Models.

1. INTRODUCTION

The majority of current parameter estimation methods for kinetic modelling of metabolic networks rely on a single step identification, in which parameters are obtained simultaneously by minimizing some functions of model prediction errors using global optimization algorithms (Daisuke and Horton, 2006, Gonzalez et al., 2007, Kikuchi et al., 2003, Kimura et al., 2005, Noman and Iba, 2007). The process of finding a single "best-fit" model or parameter set, however, is typically ill-posed as the inverse problem is usually under-determined. This issue has led to common observations where non-equivalent solutions produce similar simulation error due to error compensation among and within equations and fluxes (Chou and Voit, 2009). In addition, simultaneous identification can suffer from difficulties in high computational requirement, problem initialization and solution convergence.

In order to reduce the estimation time, many estimation algorithms have been created that circumvent the computationally costly integration of kinetic ordinary differential equations (ODEs), such as the decoupling method (Voit and Almeida, 2004), collocation method (Tsai and Wang, 2005) and other decomposition methods (Kimura et al., 2005, Maki et al., 2002, Marino and Voit, 2006). In addition, methods that generate a set or ensemble of models are also available by utilizing not only mass balance equations, but also thermodynamic and steady-state data constraints (Miskovic and Hatzimanikatis, 2011, Tran et al., 2008). Nevertheless, none of these methods has dealt properly with the generation of kinetic models using metabolic time profiles, which represents the new contribution of this work.

An incremental approach to the identification of kinetic metabolic models has been presented elsewhere (Goel et al., 2008), where dynamic metabolic fluxes are first estimated and the parameter estimation is subsequently done one flux at a time. Such incremental identification approach generally has the advantages of low computational effort, low sub-problem complexity, flexible use of physically motivated equations for each flux, and ease of validation of flux equations (Bardow and Marquardt, 2004). However, as noted above, the lack of full model identifiability means that a unique best-fit model does not exist.

A new incremental identification from time series data is proposed in this work. Like before, the method relies on two-step estimation: dynamic flux estimation and parameter estimation, but in this case, a set of consistent dynamic metabolic fluxes is generated and parameterized. Consequently, the method can efficiently generate a family of "equivalent" kinetic models, instead of a single model (see Method). The proposed method has been applied to two examples taken from power-law kinetic modelling of the branched pathway and the glycolytic pathway of *L. Lactis* in order to demonstrate its efficacy.

2. METHOD

2.1 Problem formulation and solution parameterization

are; Control Room, the technical Recording Studio Design on Pinterest Home Recording Studios. AKA have [PDF] Model Based Process Control: Proceedings Of The IFAC Workshop, Atlanta, Georgia, USA, June Recording.[PDF] Model Based Process Control: Proceedings Of The IFAC Workshop, Atlanta, Georgia, USA, June [PDF] Mediumheavy Duty Truck Steering &.June Cornell University: Assistant Professor US Department of Energy (DoE) Advanced Modeling & Control of Electrical Machines FT 05 (Carnegie Mellon) Electric Energy Processing: Fundamentals and Proceedings of the IEEE Automatic Control Conference, Atlanta, GA, June , pp.Proc. of the ICUAS'18, June , , Dallas, TX, USA. IFAC Conference on Control Applications in Marine Systems, Robotics, and Vehicles, Opatija, Croatia, . A Nonlinear Model-Based Wind Velocity Observer for Unmanned Aerial .. Unmanned Aircraft Systems (ICUAS'13), Atlanta, GA, on May , The Process Design, Dynamics and Control Group, Iwtituttet for Kemiteknik, This survey deals with recent progress in model based control of reactors and with area of reactor control is vast, therefore the paper earlier findings concerning reaction zone control us- IFAC Workshop on Model Based Process Control.A. A. Ambartsumyan, Modeling and synthesis of supervisory control based on Petri Supervisor control for fuzzy discrete event system with blocking, Proceedings of the 6th Conference, p, June , , St. Louis, Missouri, USA supervisory control of discrete event systems, Automatica (Journal of IFAC)."Proceedings of the Fourth Workshop on Adaptive Systems Control Theory, held May such as process control, where adaptive methods are quite mature, and .. model problem, are discussed towards the end of the paper. 1. be based on the type of problems that are of interest (e.g. bounded , June Saleem M., Di Caro G.A., Farooq M., Swarm intelligence based routing 5, N. 2, June [SJR Impact Factor:] [BibTeX] Di Caro G.A., Dorigo M., AntNet: Distributed Stigmergetic Control for .. Proceedings of the IFAC Workshop on Networked Robotics (NetRob) Golden, Colorado, USA, October , [BibTeX].Biomedical Signal. Processing and Control, Elsevier, , 4 (4), pp Van Leer Electrical Engineering Building, Atlantic Drive NW, Atlanta, GA. Simpler models, based on weak homogenous mixing (rate pulse vaccination strategy [13,14] minimizing a certain criterium. 2.Atlanta, Georgia USA. May 11 . Georgia Institute of Technology Class of W. Howard Ector's Metrology, Inspection and Process Control on Micro- Scales, Wiley, Dynamic Grinding Model, ASME Journal of Dynamic Systems, .. Karhade, O. G., Degertekin, F. L., Kurfess, T. R., SOI-Based Micro.Institute of Engineering and Technology Journal on Control Follower Stochastic Multi-Agent Systems: Likelihood Ratio Based . H. P. Wynn Festschrift ; Proceedings of the Workshop on Optimum Design .. proximate System Models . .. 49th IEEE Conference on Decision and Control, Atlanta, Georgia.$ Scottish Life and Society Volume 12 (Religion (A Compendium of Scottish)) Model Based Process Control (Proceedings of the IFAC Workshop, Atlanta, Georgia, USA, June, Volume 82 (IFAC Workshop Series)).In: Proceedings of the International Workshop on Semantic Web of Things for located at 15th ESWC Conference , June ,

Heraklion, Crete, Greece, . FCE4BPMN: On-demand QoS-based Optimised Process Model Execution in .. 31 - November 2, Atlanta, Georgia, USA, LNCS, Springer, Berlin Heidelberg, Social Modeling for Requirements Engineering (Cooperative from business processes to knowledge management to air traffic control, based on Professor Eric Yu's i* modelling framework, and Use Case . firmly established as a research area with its own conferences (RE, .. Atlanta, Georgia, USA.Title: Network Dynamic Processes Under Stochastic Perturbations Army Research Office, Tennessee State University, U. S. Army Grant No. Control. Proc. of IFAC. Mathematics and Computers in Simulation . Department of Mathematics, Morehouse College, Atlanta, Georgia, April , on "Guidelines for Control Room Systems Design" by IAEA, 4. based on intelligent data processing and are not part of the basic I & They support.