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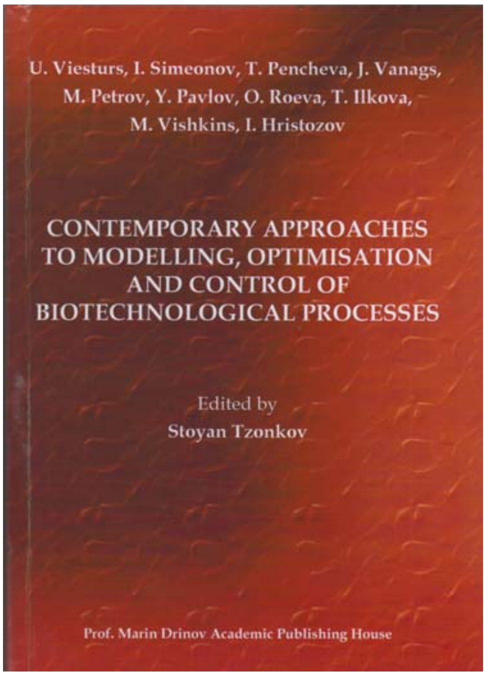
(EDITED BY STOYAN TZONKOV)

CONTEMPORARY APPROACHES TO MODELLING, OPTIMISATION AND CONTROL OF BIOTECHNOLOGICAL PROCESSES



Prof. Marin Drinov Academic Publishing House
ISBN: 978-954-322-384-8
242 pages
January 2010

The present book has a monographic nature and contains scientific results in the field of contemporary approaches to modelling, optimisation and control of biotechnological processes. The book intends to present the results of international collaboration within the EU Project FP7 "*The Implementation of Research Potential of the LSIWC in the European Research Area (WOOD-NET)*" by scientists of the *Centre of Biomedical Engineering – Bulgarian Academy of Sciences*, *Latvian State Institute of Wood Chemistry*, *Joint-Stock Company "Biotehniskais centrs" – Latvia* and *Institute of Microbiology and Biotechnology – University of Latvia*. The achieved results are the contribution to the development of the scientific field of bioprocess systems and can be useful for specialists, scientists and students, working on modelling, optimisation and control of biotechnological processes.

This monograph is devoted to the 70th anniversary of prof. Stoyan Tzonkov, D.Sc. – the founder and long-standing leader of the scientific field of modelling, optimization and control of biotechnological processes in Bulgaria. The book is intended to present various examples in this scientific direction at an advanced level.

Chapter 1 presents an application of functional state modelling approach to yeast fed-batch cultivation processes. Both structural and parameter identification of three yeast fed-batch cultivations have been presented identifying up to ten functional states during one cultivation. *Chapter 2* deals with mathematical modelling and automatic control of the anaerobic digestion of organic wastes in continuously stirred tank bioreactors. Mathematical models are classified within three important classes – mass balance models, black box models and heuristic models. Three different control algorithms are presented – optimal start-up of the process with flatness-based motion planning, linearizing control of the anaerobic digestion with addition of acetate and extremum seeking control of the biogas flow rate via the dilution rate. In *Chapter 3* is presented a control design for stabilization of the specific growth rate of fed-batch cultivation processes. The solution contains resolutions of specific optimal control problems, including some singular optimal control problems in the field. The control design is based on Wang-Monod kinetic and on Wang-Yerusalimsky kinetic models and their equivalent Brunovsky normal form. *Chapter 4* presents the problem of determining optimal controls for fed-batch fermentation processes. A development of a robust and reliable genetic algorithm is introduced in order to achieve optimal substrate feeding trajectory based on a number of objective functions. Real fed-batch fermentation processes of *E. coli* strain *MC4110* and strain *BL21(DE3)pPhyt109* were studied. *Chapter 5* presents the problem of a multiple optimisation of a fed-batch process for whey fermentation by the strain *Kluyveromyces marxianus var. lactis MC 5*. The fermentation process is formulated as a general multiple objective optimal control problem. By using an assigned membership function for each of the objectives, the general multiple objective optimization problem can be converted into a maximizing decision problem. In order to obtain a global solution a method of fuzzy sets theory is introduced to solve the maximizing decision problem. In *Chapter 6* an approach for optimal control of fed-batch process for a whey fermentation by the strain *Kluyveromyces marxianus var. lactis MC 5* is proposed. Fed-batch fermentation is developed through neuro-dynamic programming. Model predictive control is developed to guarantee robustness of the process disturbances. A method for application of dynamic programming with purpose optimization of fermentation process named *rollout* is also developed and presented. *Chapter 7* presents the elaboration of sliding mode controller with boundary layer for yeast fed-batch process. Comparing to conventional PI controller, sliding mode controller is showing better performance in respect to the task tracking and faster convergence. The obtained results show the promising possibility for a successful implementation of sliding mode controller with boundary layer to a real fermentation process. In *Chapter 8* a concept of advanced bioprocess controller, easily adaptable for different microbial fermentations, has been developed. The design includes also the rules of cascaded control of pO_2 under different fed-batch conditions. Application examples of fed-batch fermentations under different control modes are demonstrated.

Table of Contents