2012 International Conference on Technology and Management
Lecture Notes in Information Technology, Vol.21

Fuzzy Modelling of P-type Microbial Growth Model for Ethanol Fermentation Process and the Optimal Control Using Simulink

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Keywords: Fuzzy modelling, Ethanol Fermentation process, Optimal control, Simulink.

Abstract. In this work, the sector nonlinearity of Takagi-Sugeno(T-S) fuzzy system is used to represent the fuzzy model of P(roduct)-type microbial growth model for ethanol fermentation process. The optimal control for the T-S fuzzy system is computed using simulink. The objective is to provide the optimal control by the solutions of the matrix Riccati differential equation (MRDE). In this paper, the numerical example is presented together with the proposed method.

1. Introduction

The complexity of the biological world which are inherently filled with uncertainties and nonlinear systems, has open its door to the world of fuzzy logic. Studies have shown that fuzzy logic to be the most suitable tools to represent complicated biological system such as in biomedical and computational biology [1,2]. In the T-S fuzzy model, there are two types of T-S fuzzy structures which are denoted as affine and linear T-S fuzzy system. Both are demonstrated to be universal approximations to any nonlinear systems [3]. The only difference is just within the existence of a constant singleton in the fuzzy rule consequence for the affine T-S fuzzy model.

This paper adopts the nonlinearity sector of T-S fuzzy model for representing the P-type microbial growth model for ethanol fermentation process. This novel model types [4] was constructed due to the incapability of the widely used growth model of Baranyi and Roberts [5] to describe more complicated and realistic situations. Thus, a novel class of modular extendable predictive growth models with mechanistically inspired inhibition function was developed by Van Impe et al. [4,6]. The details of the P-type model can be found in Ref[4].

In the present work, the implementation of T-S fuzzy system brings in the optimal control. The optimal feedback with minimum cost control has been characterized by the solution of a Riccati equation [7]. This equation, contributes significantly in optimal control problems, multivariable and large scale systems, scattering theory, and radiative transfer. The solution of this equation is difficult to obtain from two points of view. One is nonlinear and the other is in matrix form. Generally, in order to solve MRDE with a terminal boundary condition, most of the existing methods suggested that the MRDE need to be transformed into an equivalent linear differential Hamiltonian system [8]. Another approach is to transform the MRDE into a linear matrix differential equation and then solve the MRDE either analytically or computationally [9-10]. The present paper implements the Simulink tool that are capable to create a block of diagrams which can be translated into a system of ordinary differential equations for solving the matrix Riccati fuzzy differential equations in order to get the optimal solutions. This paper is organized as follows. In section 2, the materials and methods are given. In section 3, the numerical example is discussed