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Application of fuzzy logic for the control of CSTR

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ABSTRACT

Continuous stirred tank reactor system is a typical chemical reactor system with complex non linear dynamic characteristics. There has been considerable interest in its state estimation and real time control based on mathematical modeling. However, the lack of understanding of the dynamics of the process, the highly sensitive and non linear behavior of the reactor, has made difficult to develop the precise mathematical modeling of the system. An efficient control of the product concentration in CSTR can be achieved only through accurate model. In this paper, attempts are made to alleviate the modeling difficulties using "Artificial Intelligence" (AI) techniques such as neural, fuzzy and neuro-fuzzy. Simulation results demonstrate the effectiveness of Artificial Intelligence modeling techniques. The performance comparison of different modeling techniques has been given in terms of root mean square error.

Introduction

Developing mathematical models of non-linear systems is a central topic in many disciplines of engineering. Models can be used for simulations, analysis of the system's behavior, better understanding of the underlying mechanisms in the system, design of new processes and design of Controllers. In a control system the plant displaying nonlinearities has to be described accurately in order to design an effective controller. In obtaining the mathematical model, the designer follows two methods. The first one is to formulate the model from first principles using the laws governing the system. This is generally referred to as mathematical modeling. The second approach requires the experimental data obtained by exciting the plant and measuring its response.

This is called system identification and is preferred in the cases where the plant or process involves extremely complex physical phenomena or exhibits strong nonlinearities.

Obtaining a mathematical model for a complex system is complex and time consuming as it often requires some assumptions such as defining an operating point and doing linearization about that point and ignoring some system parameters, etc. This fact has recently led the researchers to exploit the AI techniques using fuzzy tools in modeling complex systems utilizing solely the input-output data sets.

Fuzzy Logic have been increasingly in use in many engineering fields since their introduction as mathematical aids by McCulloch and Pitts in 1943, and Zadeh in 1965 respectively. Being branches of Artificial Intelligence, both emulate the human way of using past experiences, adapting itself accordingly and generalizing.

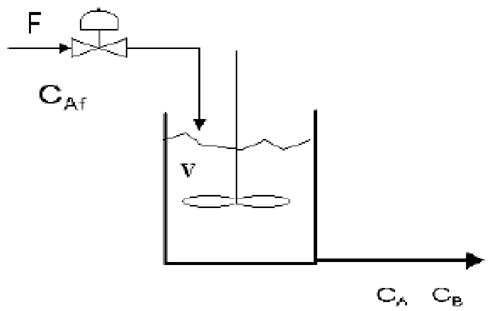
I. Cstr modeling:

The modeling of reactor is done as follows. We have modeled non isothermal CSTR. The following are the parameters we have taken to model the CSTR: Ca = x (1); T = x (2); Ea = 32400; k0 = 0.03; R = 1.987; V = 1.25lit; F= 3000m^3/lit; Caf = 0.132 gmol/lit; A = 89cm^2;

ra = k0* Ca ------------ (1)

dCa = (F/V)*(Caf-Ca) -ra; --------------- (2)

We have created a simulink model for the cstr with the help of the above sets of equations and constants.



II. Control Methods:

Here we have used fuzzy control to solve this non-linear system; mainly we concentrated to sort out the optimum flow rate at which we can get more conversion.

Fuzzy control: FLC is based on the original work of Zadeh on fuzzy set theory[7]. Its first implementation to control physical processes was proposed by Mamdani [2,3,4]. Since then, several other applications were reported [5,6]. Recently, FLC received more interest due to its successful application to important industrial systems [1,8]. Since FLC can adapt itself to changing situations, it can outperform conventional PI controllers for unstable dynamics and nonlinear systems. In contrast to model-based controllers, FLC is known as knowledge based controllers, that does not require a mathematical model of the process at any stage of the controller design and implementation. In many cases, the phenomenological model of the control process may not exist or may be too expensive in terms of computer processing power and memory, and a system based on rules of human knowledge may be more effective. In this case, FLC is a simple alternative to model-based advanced controllers.

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III. Selection of input and output variables:

The first stage of fuzzy modeling is the selection of performance variables. Here the input and output variables of the CSTR process are selected. The goal is to find the input variables, which can be best, discriminated, and are not affected by noise. The past values of concentration of B component and dilution rate are taken as inputs. The output is value of Concentration of B component. When there is moderate number of input variables in a model, the complexity of the model is reduced. Possible universe of discourse for the input and output parameters is:

Input parameters:

• Flow rate of A = 2.5 to 12.5LPH

• Flow rate of B = 5 to 15LPH

Output parameter:

• Conversion of A component = 70% to 5%

IV. Selection of Fuzzy Inference system:

There are two different solutions of fuzzy inference system. Two well known fuzzy modeling methods are the Tuskamoto fuzzy model and Takagi-Sugeno-Kang fuzzy model. In the present work, only TSK model has been considered. TSK fuzzy models are suitable for large class of nonlinear systems.

Determination of Number and type of membership functions for each variable:

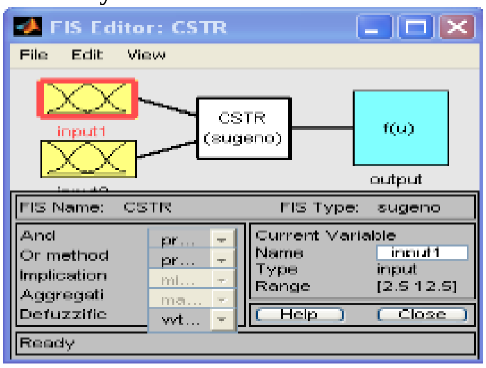
This choice determines the level of detail (granularity) of the model. Again, the purpose of modeling and the detail of available knowledge will influence this choice. The design of the fuzzy control system starts with establishing certain quantization levels for concentration of B and dilution rate along with membership functions corresponding to these quantization levels. This process defines the appropriate fuzzy sets to be the basis for applying fuzzy logic. These serve as linguistic values to be assigned, respectively, to the fuzzy variables. When the number of fuzzy sets in a input variable is moderate, reasonable labels can be assigned to fuzzy sets. In the present problem five levels for each input and output with Gaussian membership functions are used.

V. Design of rules:

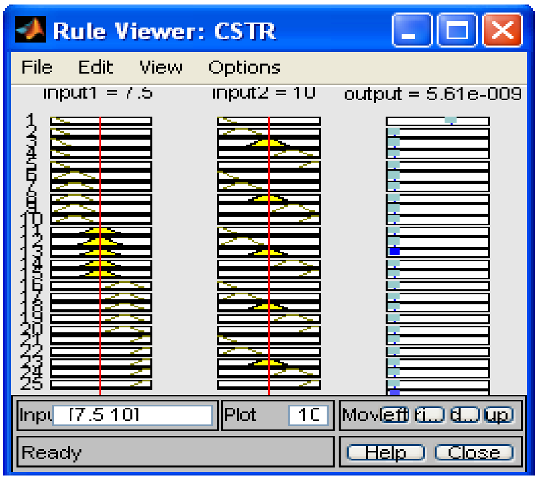
The good adequacy of the identified model allows us to synthesize the control algorithm .In the undertaken model two inputs; and one output, has already been identified. By taking into account the number of membership functions and the constraint associated with CSTR, the

Fuzzy base containing certain set of rules was designed from the expert knowledge. A Total of 25 fuzzy rules are developed. This control algorithm as fuzzy rules generates geometric representation of the model. When the number of rules is moderate, the overall behavior of the model is easier to comprehend. This surface is known as control surface and is shown in figure.

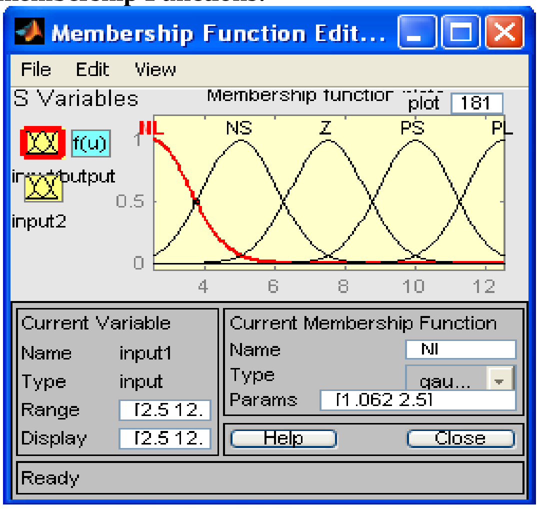
Fuzzy Inference System:



Fuzzy Rules:



Fuzzy membership Functions:



VI. Conclusion:

It is generally not possible to derive an accurate model of a process or plant especially with nonlinearities. If a reliable model is not available, it is quite difficult to design a controller producing desired outputs. When the data set does not represent the whole operating range adequately, the model to be obtained will not be as robust. Traditional modeling techniques are rather complex and time consuming when we incorporate entire dynamics of the process. However, soft computing techniques namely neural, fuzzy, neuro-fuzzy schemes can approximate the process, using input-output data sets. In the present work, modeling of CSTR was carried out using the above soft computing techniques. The models formulated capture the nonlinearity present in the CSTR. The models thus developed can be used in designing model based control schemes which offers robust controller performance.

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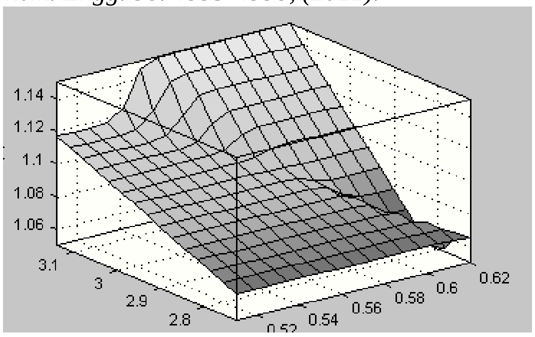

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