Temperature control of a pilot plant reactor system using a genetic algorithm model-based control approach

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ABSTRACT: The work described in this paper aims at exploring the use of an artificial intelligence technique, i.e. genetic algorithm (GA), for designing an optimal model-based controller to regulate the temperature of a reactor. GA is utilized to identify the best control action for the system by creating possible solutions and thereby to propose the correct control action to the reactor system. This value is then used as the set point for the closed loop control system of the heat exchanger. A continuous stirred tank reactor is chosen as a case study, where the controller is then tested with multiple set-point tracking and changes in its parameters. The GA model-based control (GAMBC) is then implemented experimentally to control the reactor temperature of a pilot plant, where an irreversible exothermic chemical reaction is simulated by using the calculated steam flow rate. The dynamic behavior of the pilot plant reactor during the online control studies is highlighted, and comparison with the conventional tuned proportional integral derivative (PID) is presented. It is found that both controllers are able to control the process with comparable performance. © 2007 Curtin University of Technology and John Wiley & Sons, Ltd.

KEYWORDS: genetic algorithm; model-based control; online control; chemical reactor

INTRODUCTION

Precise temperature regulation and control are crucial in a wide-range of industries including pharmaceutical, petrochemical and chemical processing. In industries, proportional integral derivative (PID) controllers are widely used because of their simplicity and effectiveness. Successful applications of the conventional controllers require the satisfactory tuning of their parameters according to the dynamics of the process. However, these tuning methods may not produce satisfactory closed-loop responses in some cases, especially when it has to deal with highly nonlinear processes that take place in chemical reactors. Therefore, the PID parameters obtained through the normally used methods, such as Cohen–Cano and Ziegler–Nichols, usually need manual retuning before being used in real processes. In order to avoid human dependency and to decrease the time taken in the tuning of PID controllers, intelligent optimal control methods based on genetic algorithm (GA) can be introduced that provide the optimized control action online.

GAs are self-propelled search techniques that mimic the process of evolution based on Darwin’s theory on survival of the fittest.1 GA employs multiple concurrent search points called chromosomes, which are manipulated through three genetic operations, reproduction, crossover and mutations, to generate new search points called offspring for the next iterations. Then, some or all of the existing population of the current solution set are replaced with the newly created population. The motivation behind the approach is that the quality of the solution set should improve with the increasing number of iterations. Thus, GA is a useful approach to problems requiring effective and efficient searching. GA has been successfully implemented in the electronic industries, for example in parameter and system identification, control, robotics, pattern recognition and classification.

Sarkar and Jayant2 have implemented optimization of fed-batch bioreactors using GA to determine the optimal feed substrate profile for the optimal operation of their fed-batch bioreactor, with an optimal production of secreted recombinant protein and a biphasic growth of yeast as their case studies. Jose Maria Nougues et al.3 demonstrated the use of GA to get the best feeding profile to minimize reaction time with temperature constraint to increase the productivity in their online batch