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Investigation on evolutionary predictive control of chemical reactor

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ABSTRACT

This paper discusses predictive control of chemical reactor by means of evolutionary algorithm named SOMA – the Self-Organizing Migrating Algorithm, that can be classified as swarm intelligence or memetic algorithm. The SOMA algorithm was used for multiple input–multiple output control of reactor model after static optimization. The MIMO control was defined for 5 inputs and 2 outputs with total number of 12 unknown variables. This paper is based on simulation results from optimization of static parameters that has been used to set up reactor for its evolutionary control.

1. Introduction

Chemical process control requires intelligent monitoring due to the dynamic nature of the chemical reactions and the non-linear functional relationship between the input and output variables involved. Chemical reactors are one of the major processing units in many chemical, pharmaceutical and petroleum industries as well as in environmental and waste management engineering. In spite of continuing advances in optimal solution techniques for optimization and control problems, many of such problems remain too complex to be solved by the known techniques.

In chemical engineering, evolutionary optimization has been applied by the author and others to system identification [16]; a model of a process is built and its numerical parameters are found by error minimization against experimental data. Evolutionary optimization has been widely applied to the evolution of neural networks models for use in control applications [11].

The area of reactor network synthesis currently enjoys a proliferation of contributions in which researchers from various perspectives are making efforts to develop systematic optimization tools to improve

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the performance of chemical reactors. The contributions reflect on the increasing awareness that textbook knowledge and heuristics [10], commonly employed in the development of chemical reactors, are now deemed responsible for the lack of innovation, quality, and efficiency that characterizes many industrial designs, [2,13,14].

The main aim of this participation is to show that evolutionary algorithms (EAs) are capable of optimization of chemical engineering processes. The ability of EAs to successfully solve optimization and predictive control of chemical reactors is demonstrated in this study.

Firstly, a nonlinear mathematical model is required to describe the dynamic behaviour of batch process; this justifies the use of evolutionary method of the EAs for deal with this process, for static optimization of a chemical continuous stirred tank reactor. Consequently, it is used to design geometry technique equipment for chemical reaction. In the next part, we have used EAs for predictive control of chemical process of reactor too. The optimized reactor and predictive control were used in a simulation with optimization by evolutionary algorithms and the results are presented in graphs.

In this paper we briefly discuss description of the chemical reactors and used EAs. Evolutionary algorithms are then studied, and finally experimental results are reported, followed by conclusion.

The use of evolutionary algorithms in optimization and control of chemical technologies is very important today and many researchers are working in that field. They are using classical as well as evolutionary algorithms for those purposes, lets mention for example [6,12,15,20] for more classical approach to solve problems of chemical technologies, [3,4,8].

Nowadays, there exists a broad class of algorithms that can be, and are, used for optimization. This special class of algorithms is made up of so-called evolutionary algorithms (EA) [1,5,7,9,17–19,23] that consist of wide spectrum of modern as well as classical heuristic methods like genetic algorithms or differential evolution algorithms, for example. Both algorithms work with so-called populations that are evolved in "generations" (or "migration loops" in the case of SOMA [21]), in which only the best-suited individuals survive.

This paper presents use of algorithm, which can be labelled an "evolutionary" algorithm – despite the fact that during its activity, no new generations are created (in a general sense). Development of this algorithm was inspired by the behaviour patterns of groups of wild animals in the wild. It has been termed "the Self-Organizing Migrating Algorithm" – or SOMA for short (for complete description, source codes etc. see [21]).

SOMA, and generally speaking any evolutionary algorithm, can be used in regards to any optimization problem. Surprisingly, many problems can be defined as optimization problems, e.g. the optimal trajectory of robot arms; the optimal thickness of steel in pressure vessels; the optimal set of parameters for controllers; optimal relations or fuzzy sets in fuzzy models; and so on. Solutions to such problems are usually more or less hard to arrive at, their parameters usually include variables of different types, such as real or integer variables. Evolutionary algorithms are quite popular because they allow the solution of almost any problem in a simplified manner, because they are able to handle optimizing tasks with mixed variables – including the appropriate constraints, as and when required.

This paper explains SOMA's use on predictive control of given chemical reactor. A large part of the research dealing with wastes of the leather industry, except for USDA publications, does not go into particulars about how to cope with chrome sludge after dechromation of tanned wastes. As if chrome sludge so formed was automatically assumed to be simply used for producing recycled tanning salt. Even though the balance of chromium in chrome-tanned wastes and of necessary tanning salt is very favourable for recycling in the tanning industry, the actual situation is different.

Although we quite correctly feel and hope that the issue of recycling chromium into the tanning industry should be worked on or at least supported by manufacturers of chromic chemicals in the first place, we studied both the drawbacks of such recycling and applications in other fields. Part of this research is focused on reactor inside which class of mentioned chemical reactions could be done. Main aim of SOMA use was for reactor optimization of static parameters, see [22] and control of reactor under this setting.