Dynamic Multi-objective Optimization and Decision-Making Using Modified NSGA-II: A Case Study on Hydro-thermal Power Scheduling

Kalyanmoy Deb, Udaya Bhaskara Rao N., and S. Karthik

Kanpur Genetic Algorithms Laboratory (KanGAL)
Indian Institute of Technology Kanpur, PIN 208016, India
deb@iitk.ac.in, uday.iitk@gmail.com, ksindhya@iitk.ac.in

Abstract. Most real-world optimization problems involve objectives, constraints, and parameters which constantly change with time. Treating such problems as a stationary optimization problem demand the knowledge of the pattern of change a priori and even then the procedure can be computationally expensive. Although dynamic consideration using evolutionary algorithms has been made for single-objective optimization problems, there has been a lukewarm interest in formulating and solving dynamic multi-objective optimization problems. In this paper, we modify the commonly-used NSGA-II procedure in tracking a new Pareto-optimal front, as soon as there is a change in the problem. Introduction of a few random solutions or a few mutated solutions are investigated in detail. The approaches are tested and compared on a test problem and a real-world optimization of a hydro-thermal power scheduling problem. This systematic study is able to find a minimum frequency of change allowed in a problem for two dynamic EMO procedures to adequately track Pareto-optimal frontiers on-line. Based on these results, this paper also suggests an automatic decision-making procedure for arriving at a dynamic single optimal solution on-line.

1 Introduction

A dynamic optimization problem involves objective functions, constraint functions and problem parameters which can change with time. Such problems often arise in real-world problem solving, particularly in optimal control problems or problems requiring an on-line optimization. There are two computational procedures usually followed. In one approach, optimal control laws or rules are evolved by solving an off-line optimization problem formed by evaluating a solution on a number of real scenarios of the dynamic problem [11]. This approach is useful in problems which are computationally too expensive for any optimization algorithm to be applied on-line. The other approach is a direct optimization procedure on-line. In such a case, the problem is considered stationary for some time

S. Obayashi et al. (Eds.): EMO 2007, LNCS 4403, pp. 803–817, 2007.

period and an optimization algorithm be allowed to find optimal or near-optimal solution(s) within the time span in which the problem remains stationary. Thereafter, a new problem is constructed based on the current problem scenario and a new optimization is performed for the new time period. Although this procedure is approximate due to the static consideration of the problem during the time for optimization, efforts are made to develop efficient optimization algorithms which can track the optimal solution(s) within a small number of iterations so that the required time period for fixing the problem is small and the approximation error is reduced. In this paper, we consider solving dynamic optimization problems having more than one objective function using the direct on-line optimization procedure described above.

Although single-objective dynamic optimization has received some attention in the past [2], the dynamic multi-objective optimization is yet to receive a significant attention. When a multi-objective optimization problem changes with time in stepped manner, the task of an dynamic EMO procedure is to find or track the Pareto-optimal front as and when there is a change. After the idea has been put forward earlier [6], there has been a lukewarm interest on this topic [8,7]. In this paper, we suggest two variations of NSGA-II for tracking dynamic Pareto-optimal frontiers. The effect of frequency of change in a problem and the proportion of added random or mutated solutions are parameters which are systematically studied to evaluate the developed procedures for their tracking efficiency. The proposed NSGA-II procedures are applied to a complex hydro-thermal power scheduling problem involving two conflicting objectives. The change in problem appears due to a change in demand in power with time. The efficacy of modified NSGA-II procedures is illustrated by finding the smallest frequency of change which can be allowed before the EMO procedures can track the optimal front with a significant confidence. Finally, a decision-making aid is coupled with the dynamic NSGA-II procedures to help identify one solution from the obtained front automatically (on-line). Interesting conclusions about the particular problem and about dynamic multi-objective optimization problem, in general, are made from this study.

2 Dynamic Problems as On-Line Optimization Problems

Many search and optimization problems in practice change with time and therefore must be treated as an on-line optimization problems. The change in the problem with time t can be either in its objective functions or in its constraint functions or in its variable boundaries or in any combination of above. Such an optimization problem ideally must be solved at every time instant t or whenever there is a change in any of the above functions with t. In such optimization problems, the time parameter can be mapped with the iteration counter τ of the optimization algorithm. One difficulty which may arise in solving the above on-line optimization task is that the underlying optimization algorithm