GAs in Global Optimization of Mixed Integer Non-Linear Problems

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The global optimization of mixed integer non-linear problems (MINLPs), constitutes a major area of research in many engineering applications. MINLPs have always been considered difficult problems. In particular, gradient optimization techniques have only been able to tackle special problem formulations, where continuity and convexity had to be verified, or by exploiting the mathematical structure. However, there are a number of problems which do not satisfy these conditions. These problems arise in many engineering applications. Evolutionary algorithms present a new possibility in tackling these problems. The general formulation of the problem is as follows:

$$\min f(x) \text{ subject to } h(x) = 0,\ g(x) \leq 0$$
$$x_j \text{ integer },\, j \in I,\ x \in X = \left\{\mathbf{x} \mid \mathbf{x} \in R^n, \mathbf{x}^l \leq \mathbf{x} \leq \mathbf{x}^u\right\}$$

In this work, seven test problems, proposed by independent authors, are studied using Genetic Algorithms (GAs). These problems arise from the area of chemical engineering, and represent difficult nonconvex optimization problems, with continuous and discrete variables. Comparisons are made with an NE-SIMPSA algorithm (Cardoso et al.1997) based on the combination of the non-linear simplex method of Nelder and Mead and Simulated Annealing.

Most of GAs implementation on constrained optimization use the penalty function method (Goldberg 1989). This approach has a major drawback. The setting of the penalty parameters usually requires extensive experimentation. In this work, we compare this approach with the constraint handling method proposed by Deb (1998). A penalty term is introduced which does not depend on a penalty parameter. In this approach, two solutions are compared on the base of their objective function values, if feasible; and on the constraint violations, if infeasible. Furthermore, any feasible solution will have a better fitness function value than any infeasible solution.

In this work no tuning of the GAs parameters was used, since the objective was to see how it would work as a general problem solver. The results seem to indicate that the performance of GAs is very dependent on the penalty coefficient values, which suggest the necessity of investigating different schemes to deal with the constraints as the one suggested by Deb (1998). This scheme has the great advantage of not demanding any experimentation for fixing the penalty parameter value. However, GAs show difficulties in dealing with equality restrictions using a penalty scheme, but exhibiting a good behavior when these constraints were formulated as inequalities. GAs performance, in terms of the number of convergencies to the optimum, was good when compared with other approaches, such as simulated annealing and random search (Cardoso et al. 1997); in fact, for one of the problems considered, a better solution was found than the one previously reported; on the other hand, the mean number of function evaluations was superior to the mean number reported by other algorithms. However, with the handling of the constraints according to Deb (1998), GAs are clearly superior since no infeasible point can have a fitness value superior to a feasible point, which can happen in the approach of Cardoso et al. (1997). Thus, GAs seem to be a valid approach in tackling real world MINLP problems.

References

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