New Multicriteria Optimization Method Based on the Use of a Diploid Genetic Algorithm: Example of an Industrial Problem

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Abstract. The design of a new product or of its manufacturing process consists in reconciling multiple objectives with each other to take into account their different features. In this paper, a new multicriteria optimization algorithm is presented. This method is based on the use of (i) a genetic algorithm (GA) which optimizes each system response and (ii) a selection algorithm which sorts Pareto-efficient points. This technique presents the great advantage of being of wide use. There is no particular mathematical condition about functions that are simultaneously optimized and, unlike the other multicriteria optimization methods which depend on the user’s choice, our algorithm permits to obtain an optimal surface in which the user will be able to pick up his own working conditions. Efficiency of this new method is here illustrated with one mathematical example and with an industrial application.

1 INTRODUCTION

In a lot of domains, processing or product formulation depend on several criteria and consequently industrials are often confronted with multicriteria decision problems. Food processes are a good illustration for this case. For example, it can be necessary to optimize different parameters such as texture, flavour, and so ever, in order to formulate a new product or else, before to use bacteria or yeasts, it is very interesting to maximize yields, production and product quality with minimal investment whereas these four criteria are not optimal for the same working conditions. To help to solve such problems, traditionnally, objectives were whether all combined to form a scalar objective, through a linear combination of multiple attributes [2] or a geometric average of these ones [3]. In an other classical method, a function, called primary response function, was optimized whereas the others, called secondary response functions, were turned into constraints [8]. These two techniques depending on the user’s choice, for weights or constraints determination, they are consequently not adapted to solve multiple objective problems found in food industry where it will be more interesting to find a compromise solution.
Methods incorporating a domination criterion are more interesting because they are of more general use and more accurate. For example, an interactive algorithm permits a reference direction approach [9]. The decision maker has to choose his solution in a set of solutions which are not dominated. A solution is nondominated or Pareto-efficient if no other solution exists that is equally good for every objective and better for at least one of them [10], [7]. This algorithm generates Pareto-optimal alternatives without defining the whole Pareto area and the solution depends on the user's choices. In this case, a set of points that are the nondominated solutions, is defined. The domination criterion of Pareto is widely used to perform multicriteria optimization [6], [11] and [5]. The definition of the zone of Pareto is easy but it is more difficult to determine it practically.

A method based on a diploid GA previously elaborated [1], [4] and a nondominated solutions selection procedure has been developed [12] to define a set of Pareto-efficient points. This algorithm performs the simultaneous minimization of functions. The maximization of $f_i$ being equivalent to the minimization of $-f_i$. As a consequence, the search of working conditions concerning a culture medium which maximize quality and production and minimize investment no more represents any problem. The number of real-valued decision variables and the constraints can be different for each function.

This new method is presented through the intermediary of the two algorithms it uses. It is then illustrated with one mathematical example. In the last section, this technique is compared with two classical methods on an industrial application.

2 DESCRIPTION OF THE ALGORITHM

2.1 Genetic algorithm

Fonteix et al.,[4] proposed a GA which modelizes the genetic of diploid individuals. This GA has been compared with a haploid one [1] and its performances were found to be better that is why we used the diploid version.

Each individual (which can be a possible solution of the problem) is described by a four-tuple $(a_j, a'_j, D_j, x_j)$. $a_j$ and $a'_j$ represent the two alleles of one gene. The genotype is composed of two chromosomes and phenotype, $x_j$, is the result of the combination of the respective alleles, $a_j$ and $a'_j$, with the respect to the dominance, $D_j$, of one allele over the other. $D_j$ is a value randomly chosen in $[0, 1]$ interval; it is a specific value for the both alleles of each gene. An initial population is created by generating a set of N points (or individuals) from the search space. Each point is tested and evaluated. If this population is not the solution, then probabilistic rules are used to make it evolve. Only the better individuals will survive (elitist selection) and participate to the creation of a new generation. The reproduction of the individuals in the diploid model is characterized by a multi-crossover on the two chromosomes of each parent, and by the mutation and the homozygosity [4]. When a child is created, it is tested with respect to all constraints which must be satisfied; if not, it is rejected and