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Ensemble of niching algorithms

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ABSTRACT

Although niching algorithms have been investigated for almost four decades as effective procedures to obtain several good and diverse solutions of an optimization problem, no effort has been reported on combining different niching algorithms to form an effective ensemble of niching algorithms. In this paper, we propose an *ensemble of niching algorithms* (ENA) and illustrate the concept by an instantiation which is realized using four different parallel populations. The offspring of each population is considered by all parallel populations. The instantiation is tested on a set of 16 real and binary problems and compared against the single niching methods with respect to searching ability and computation time. Results confirm that ENA method is as good as or better than the best single method in it on every test problem. Moreover, comparison with other state-of-the-art niching algorithms demonstrates the competitiveness of our proposed ENA.

1. Introduction

In real-world optimization problems, sometimes we are not satisfied with only one optimal solution. The demand for multiple solutions is more prominent when there exist several near optimal answers to a problem. Simple genetic algorithms [1,9] often lack the ability to locate multiple optima, thus, niching methods are introduced. They are used to solve these problems as they attempt to maintain a diverse population and are not as prone to converge prematurely as simple genetic algorithms.

The concept of niching is inspired by the way organisms evolve in nature. In ecology, a "niche" is a term describing the resources and physical space which a species depends on to exist in the ecosystem; it is an environment in which inhabitants take up their roles, deal with the distribution of resources and competition, and at the same time alter those factors. Within a niche, individuals are forced to share the available resources, whereas among different niches, there will be no conflict for the resources.

In evolutionary computation, niching involves the formation of subgroups within a population where each subgroup targets a specific task such as discovering one peak in a multimodal function. Compared with the simple genetic algorithm, the uniqueness of niching genetic algorithms lies in the fact that they preserve not only the highly-fit individuals, but also weaker individuals so long as they belong to groups without the highly-fit ones. This gives the population an opportunity to pass the genetic information of such individuals to their offspring, and it ensures that this information does not become extinct

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quickly. By maintaining a reasonably balanced variety of genetic information, niching procedures allow the population to simultaneously focus on more than one region in the search space, which is essential to discover several optima in a single run.

Since the earliest niching approach, *preselection*, was proposed by Cavicchio [5] in 1970, various niching methods such as crowding [8,34,35,22,6,31], sharing [15,18,59,38,20,16,21,33,12], and clearing [42,29,28] have emerged. However, so far, to solve a certain problem, only one method is used at a time. It is often the case that we have to try out several niching methods and tune their parameters to find the best method and its best set of parameters to solve a given problem. Irrespective of the exhaustiveness of the parameter tuning, no one method can be the best for all problems. The various niching methods divide the population into niches where the same selection and survival criteria are implemented. Instead of that, we can establish several populations, each of which can employ a distinct niching algorithm. The existing niching methods offer us a wide choice of combinations in this scenario.

In this paper, we propose the ensemble of niching algorithms (ENA) which uses several niching methods in a parallel manner in order to preserve diversity of the populations and to benefit from the best method. An instance of ensemble is presented to illustrate the ENA concept. It is tested using a set of 16 multimodal test functions in real and binary domains. Results demonstrate that the performance of ENA is more competitive than that of the constituting individual niching methods.

The rest of the paper is organized as follows. Section 2 discusses the existing niching algorithms. Section 3 presents a description of the proposed ensemble of niching algorithms, including when to use the ENA, the procedures, and some implementation details. The fourth section introduces the test problems. In Section 5, evaluation criteria and parameter settings are given. Section 6 reports the results in terms of searching ability and computation time. Comparisons between ENA and the single methods are also investigated in Section 6. Section 7 presents further comparisons with state-of-the-art niching algorithms. Section 8 concludes the paper.

2. Niching algorithms

2.1. Crowding and restricted tournament selection

The crowding methods encourage competition for limited resources among similar individuals in the population. They follow the analogy that dissimilar individuals tend to occupy different niches, so that they typically do not compete. The end result is that in a fixed-size population at equilibrium, new members of a particular species replace older members of that species, and the overall number of members of a particular species does not change [34]. They make use of a distance measure (either in genotype or phenotype space) to determine similarity between individuals and inserts new members into the population by replacing similar ones. Belonging to this category are *crowding* [8], *deterministic crowding* [34,35], *restricted tournament selection* (RTS) [22], and so on.

Crowding [8] was introduced in De Jong's dissertation in 1975. The algorithm allows only a fraction of the population to reproduce and die in each generation. A percentage of the population, specified by the *generation gap*, is chosen via the fitness-proportionate roulette wheel selection to go through reproduction. For every newly-created individual, *CF* (a number called crowding factor) individuals are randomly taken from the population and the most similar to the new individual (either in a genotypic or a phenotypic sense) is replaced. Fitness values are not considered in the replacement procedure.

Mahfoud [34,35] proposed deterministic crowding as an improvement for crowding. The algorithm dispenses with the fitness-proportionate selection of crowding, and randomly selects two parents from the population instead to perform crossover and mutation. In order to have selection pressure and minimize replacement error that can occur in preselection, the two offspring replace their closest parent if the offspring has higher fitness. No parameters in addition to those of a simple genetic algorithm are used in the algorithm.

Restricted tournament selection [22] adapts tournament selection for multimodal optimization. Like deterministic crowding, it selects two parents from the population to generate two offspring by performing crossover and mutation. After that, for each offspring, the algorithm chooses a random sample of w (window size) individuals from the population and determines which one is the nearest to the offspring, by either Euclidean (for real variables) or Hamming (for binary variables) distance measure. The nearest member within the w individuals will compete with the offspring to determine who has higher fitness. If the offspring wins, it is allowed to enter the population by replacing its opponent. As more and more highly-fit individuals enter the population, this method should force tougher competition for spots to be held between members of the same niche, but at the same time it allows other niches to flourish. The RTS is shown in Fig. 1.

Many algorithms make use of the crowding concept. *Multi-niche crowding* [6], for example, utilizes some type of crowding in both the selection and replacement steps.

2.2. Sharing and clustering

In sharing methods, similar individuals are penalized by a reduction in their fitness values, as they share the limited resource of that niche. The standard *fitness sharing* [18] uses a sharing radius which is defined beforehand and usually fixed throughout the niching process. The population member i's fitness, called the shared fitness, is given by: