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Convergence of nomadic genetic algorithm on benchmark mathematical functions

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ABSTRACT

Nomadic genetic algorithm is a type of multi-population migration based genetic algorithm that gives equal importance to low fit individuals and adaptively chooses its migration parameters. It has been applied to several real life applications and found to perform well compared to other genetic algorithms. This paper exploits the working of nomadic genetic algorithm (NGA) for benchmark mathematical functions and compares it with the standard genetic algorithm. To compare its performance with standard GA (SGA), the prominent mathematical functions used in optimization are used and the results proved that NGA outperforms SGA in terms of convergence speed and better optimized values.

1. Introduction

Genetic algorithms [1,2] are a part of evolutionary computing which is a rapidly growing area of artificial intelligence. They are adaptive methods used to solve search and optimization problems. They are based on the genetic processes of biological organisms. By mimicking the principles of natural evolution, i.e. “Survival of the Fittest”, GAs are able to evolve solutions to real world problems.

This paper describes both standard genetic algorithm and a variant of the standard genetic algorithm called nomadic genetic algorithm. It is a specialized form of genetic algorithm that works on the principle of “Birds of the same feather flock together”. Generally in standard GA different kinds of selection mechanisms like Roulette wheel selection, rank based selection, tournament selection, etc. are employed based on the type of application. All these selection mechanisms aim to select high fit individuals in different proportion for the purpose of mating. The low fit individuals are given very less chance for mating or they are totally discarded in some selection schemes thus reducing the diversity in the population. But the worst individuals, if given a chance may also result in better offspring in the next generation. This phenomenon is given importance in this variant of standard GA. Here, the individuals in the population are grouped into different communities or groups, based on their fitness value. Individuals, in a community mate with each other. Here again, different kinds of selection mechanisms could be used within the community. If any offspring comes up with a better fitness, it leaves its community and joins a different community, i.e. the group of similar fitness value. It employs most of the principles of standard GA except that, it allows for migration of individuals within the different communities in the population that the individuals are grouped into. The selection procedure followed in nomadic genetic algorithm insists on mating within the same community thus providing equal chances of mating even to the weakest section of the population. This allows the nomadic genetic algorithm to maintain the diversity of individuals in the population, also ensuring faster convergence.

To prove the performance of NGA, the benchmark mathematical functions have been taken up for implementation and testing. The same set of functions are implemented for the SGA and the results are compared in terms of the number of generations required to converge and also the optimized values.

2. Related work

Multi-population GAs [3,4] are good at faster convergence, since each sub-population evolves independent of each other. The performance of MGA is heavily affected by a judicious choice of parameters, such as connection topology, migration method,

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migration rate, and population number [5,6]. MGAs shorten the number of generations to find optimal or near optimal solutions. It is also more resistant to premature convergence. A number of multi-population genetic algorithms have been reported in literature and some of them are presented in this section.

In [26], migration occurs after each generation and a copy of best individual in each sub-population is sent to all its neighbors. Grosso [7] used 5 sub-population and exchanged individuals with fixed migration rate and proved that migration greatly influenced the performance of GA. A multi-population GA based on chaotic migration strategy [22] employs asynchronous migration of individuals during parallel evolution and proved its immunity against premature convergence.

A number of mechanisms for restricting the mating of individuals also have been proposed earlier [8]. Generally mating is restricted among similar individuals with the notion that similar parents produce similar offspring, which will not produce diversity in the population. Booker [9] and Goldberg [23] have explored various approaches in which a mating tag is added to each individual. The tag must match before a cross is permitted. Another type of mating restriction is introduced by Spears [10] which adds a one dimensional ring topology and restricts mating to neighbors with identical tags.

To maintain the diversity of individuals in a population, migration has also been attempted earlier [27,28], but with parallel GAs like in Genitor II by Whitley [30], wherein individuals migrate from one processor to another. According to Tanese [11,12], genetic algorithms that incorporate migration are reported to produce more population diversity.

Even though there are several types of multi-population GAs, they have not addressed the issue of selection bias present in genetic algorithms. Different kinds of selection mechanisms and genetic operators have been employed to guide the random adaptive procedure of GA to explore all possible solutions. Simple GA's selection mechanism replicates higher fitness solutions and discards lower fitness solutions leading to convergence of the population. For instance, Brindle [31] has proved the inferior performance of Roulette wheel selection on several test functions. Also, Baker [13] has analyzed various fitness proportionate selection methods. The ultimate aim of these selection methods is achieving diversity [25] as it is considered to be an important goal to reach a global optimum solution. Some GAs primarily rely on mutation or mutation like mechanisms for diversification [14].

There is always a trade-off between convergence and diversity in GA. To balance both these aspects, the nomadic genetic algorithm has been proposed which allows beneficial search as well as controlled convergence.

3. Nomadic genetic algorithm

In the previous section, a survey of migration based GAs has been presented. Also, the different kinds of selection mechanisms have been discussed. Generally, most of the selections mechanisms are adept at choosing the best individuals for mating and subsequently make to the next generation. The low fit individuals are given very less chance of survival or none at all. This strategy, do allow the GA to converge faster, but the exploration of the entire search is not guaranteed. The importance of low fit individuals in GA had been felt by some researchers, and they have also tried to introduce some kind of mutation or a new individual to the population when it is found that the population has saturated with only high fit individuals and there is no scope for further exploration of the search space. They have resorted to several methodologies to introduce diversity in the population which is not possible if the high fit individuals are selected always.

Apart from the problems associated with the selection bias, the problems encountered with parallel GAs are also worth mentioning at this juncture. The success of any parallel GA relies heavily on the selection of the correct set of migration parameters. The parameters for parallel GA include the migration rate, migration interval and the connection topology. A proper selection of these parameters is crucial to the success of GA and many researchers have attempted several combinations of them. This paper is one such attempt wherein, the design and implementation of nomadic genetic algorithm which falls under the class of multi-population GA is presented and analyzed.

3.1. Nomadic genetic algorithm

Nomadic genetic algorithm [15,16] is a form of multi-population GA with migration capabilities, wherein, the shortcomings of selection mechanisms are removed and the virtues of parallel GA with migration has been incorporated. The concept of nomadic genetic algorithm emerged from the fact that "Birds of the same feather flock together". In the real world scenario, any living being live and mingle within its own community. Only seldom do they go for intermingling with other communities. This is an inherent feature of any species and it is being exploited in this nomadic genetic algorithm.

3.1.1. Methodology

Genetic algorithms begins with an initial population of individuals or chromosomes. In nomadic GA, the entire population is organized into several communities or groups, based on their fitness values. The number of groups depends on the population size and the number of groups, initially defined by the user. Moreover, it has been empirically proved that NGA performs well if the entire population is divided into 3 or 4 groups. For instance, if the population size is 100, number of groups is 4, then the entire population is sorted and the first 25 falls in one group, the second 25 in another and so on.

This can be compared with the societal status of an individual in the real sense. Individuals, within a community or group mate among themselves to produce their offspring. The general GA procedure is carried out within the groups, maybe selection, crossover or mutation. Once the offspring are produced, they may have different fitness values, based on which they try to migrate to a different community or group which suit their fitness level or status. But, the number of individuals in a group always remains constant throughout the GA execution. In this way, individuals keep migrating from one group to another like nomads or wanderers, depending upon their fitness level, and hence the term nomadic genetic algorithm has been coined for this method.

The specialty of this algorithm is that, the migration parameters like, migration rate, migration frequency, topology and migration policy need not be explicitly mentioned by the user. This is adaptive in nature and according to the fitness variations, the number of individuals to migrate (rate) depends on how many individuals have improved their fitness value in the subsequent generation. The question of where to migrate (topology) is again taken care of the algorithm itself. Almost in every generation, migration occurs and hence the migration frequency also need not be mentioned. Similarly, the migration policy (how individuals replace one another) also need not be specified because individuals are not replaced here, but they try to move to a different group. Fig. 1 [29] illustrates the working principle of NGA The algorithm is given in the subsequent section: