Adaptation to a Changing Environment by Means of the Feedback Thermodynamical Genetic Algorithm

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Abstract. In applications of the genetic algorithms (GA) to problems of adaptation to changing environments, maintenance of the diversity of the population is an essential requirement. Taking this point into consideration, the authors have proposed to utilize the thermodynamical genetic algorithm (TDGA) for the problems of adaptation to changing environments. The TDGA is a genetic algorithm that uses a selection rule inspired by the principle of the minimal free energy in thermodynamical systems. In the present paper, the authors propose a control method of the temperature, an adjustable parameter in the TDGA. The temperature is controlled by a feedback technique so as to regulate the level of the diversity of the population measured by entropy. The adaptation ability of the proposed method is confirmed by computer simulation taking time-varying knapsack problems as examples.

1 Introduction

Genetic Algorithms (GAs) are search and optimization techniques[1, 2] based on the mechanism of evolution by natural selection. Adaptation to changing environments is one of the most important applications of the GAs.

The GA approaches for adaptation to changing environments proposed so far are categorized into two types: If a environmental change is recurrent, i.e., if the environment appeared in the past reappears repetitively, to memorize the results of past adaptations and to utilize them as candidates of the solutions will be an effective strategy. We call such an approach the memory-based approach. In the context of GA research, several studies on this approach have been proposed. For example, methods using diplody, structured gene have been proposed[2, 3]. The authors have also proposed a method taking this approach[4].

On the other hand, if an environmental change is unpredictable, GAs have to adapt to a novel environment using only their search ability. We call such an approach the search-based approach. If the environmental change is completely random, no method will be better than the method of restarting the GA for each environment. However, if the environmental change is moderate, to search
the neighborhood of the recent solution will be an effective way. To achieve this strategy, maintenance of the diversity of the population plays an important role. That is, a GA must keep the results of adaptation to recent environments on one hand, and on the other hand, it must keep the diversity of the population to ensure their search ability.

There have been proposed several methods of the search-based approach. Grefenstette has proposed the random immigrants[5] where the population is partially replaced by randomly generated individuals in every generation. Since the randomly generated individuals are usually poor solutions, this method faces a difficulty of low online performance. Cobb has proposed the method of controlling the mutation rate called the triggered hypermutation[6], where the mutation rate is temporarily increased to a high value (called the hypermutation rate) whenever the time-averaged best performance of the GA declines. Since this method detects the environmental change using an assumption that the optimal value is always kept constant, its applicability is limited.

Both the random immigrants and the triggered hypermutation utilize random perturbation to increase the diversity of the population. We can generalize these two methods as the random perturbation method as follows:

1. The population is perturbed when the GA system receives a perturbation signal from environment.
2. Perturbation to the population is given by applying hypermutation with the hypermutation rate $m_H$ to some individuals in the population specified by the perturbation rate $\gamma$.

Assuming that binary string representation and locus-wise mutation, the random immigrants is represented by a case that the perturbation signal occurs in every generation, $m_H = 0.5$ and $\gamma$ is taken as an adjustable parameter. The triggered hypermutation is a case that the perturbation signal occurs when the time-averaged best performance declines, $m_H$ is adjustable and $\gamma = 1$. We call the simple genetic algorithm which uses this method the Perturbation SGA (PSGA).

The authors have proposed another method categorized into this approach[7]. That is, the selection operation of the GAs is designed so as to keep the diversity of the population systematically. It is called the thermodynamical genetic algorithm (TDGA)[8].

This paper proposes a modified TDGA called the Feedback Thermodynamical Genetic Algorithm (FTDGA) which controls the temperature, an adjustable parameter of the TDGA, so as to regulate the level of the entropy of the population.

2 Feedback Thermodynamical Genetic Algorithm

2.1 Thermodynamical Genetic Algorithm (TDGA)

In the selection operation used in the conventional GA, an individual having the larger fitness value is allowed to yield the more offspring in the next generation.