Mechanism of Multi-Objective Genetic Algorithm for Maintaining the Solution Diversity Using Neural Network

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Abstract. When multi-objective genetic algorithms are applied to real-world problems for deriving Pareto-optimal solutions, the high calculation cost becomes a problem. One solution to this problem is to use a small population size. However, this often results in loss of diversity of the solutions, and therefore solutions with sufficient precision cannot be derived. To overcome this difficulty, the solutions should be replaced when they have converged on a certain point. To perform this replacement, inverse analysis is required to derive the design variables from objects as the solutions are located in the objective space. For this purpose, an Artificial Neural Network (ANN) is applied. Using ANN, the solutions concentrating on certain points are replaced and the diversity of the solutions is maintained. In this paper, a new mechanism using ANN to maintain the diversity of the solutions is proposed. The proposed mechanism was introduced into NSGA-II and applied to test functions. In some functions, the proposed mechanism was useful compared to the conventional method. In other numerical experiments, the results of the proposed algorithm with large populations are discussed and the effectiveness of the proposed mechanism is also described.

1 Introduction

Since Schaffer developed the genetic algorithm for multi-objective optimization problems [14], many evolutionary multi-objective algorithms that can derive good solutions have been introduced in this field [7,19]. Recently, these algorithms have been applied to real-world problems and effective results have been obtained. [3,16] One of the most important points to obtain solutions in real-world problems is to derive a superior solution within a reasonable time. Usually, it takes a large amount of time to evaluate one parameter set in a real-world problem. Therefore, even with a strong algorithm, satisfactory results cannot be

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derived if the calculation time is of insufficient length. In this case, an algorithm that can derive reasonable solutions with a small number of evaluation calls should be used. There are two approaches to develop such algorithms.

The first approach is to use the response surface methodology [17], which is a technique for approximating objective functions. This method reduces the calculation costs by generating approximations of objective function and treating these approximations as objective functions for each evaluation. There are several response surface methodologies, such as the quadratic polynomial model [1], neural network model [2,6,11], and Kriging model [12]. Among these, the quadratic polynomial model is commonly used, because it is the simplest and has low calculation costs for approximation. Although the costs associated with the other models for approximation are greater than those for the quadratic model, the neural network model and Kriging model allow approximation of more complicated objective functions [18].

On the other hand, the method discussed here involves a search with a small number of individuals. For MOGA search, it is critical to search the Pareto-optimal solutions with keeping the diversity of individuals, because it is more likely that solutions with high accuracy and diversity will be obtained. This approach can reduce the calculation cost, but the solutions often converge on a certain point in the search process and the diversity of the solutions may be lost. In this paper, we propose a mechanism that eases the reduction of diversity of solutions during the search process by using an Artificial Neural Network (ANN). This mechanism is expected to reduce the calculation cost, and provide a good set of Pareto-optimum solutions with a high degree of diversity and accuracy, even when the search is performed with a small number of individuals.

In this paper, we discuss in detail a mechanism to ease the reduction of diversity using ANN. The proposed mechanism is introduced into NSGA-II [7], a typical MOGA, and its effectiveness and influence on the search are investigated for mathematical test functions.

2 Problem of Multi-Objective Genetic Algorithms with a Small Population

The advantage of multi-objective optimization using a MOGA is that it can derive several Pareto-optimum solutions in one calculation trial. However, a number of function evaluations are required before the Pareto-optimum solution can be obtained. The calculation cost can be reduced when using a small number of individuals or a small number of generations. However, with this approach, the diversity of individuals is often lost. This may have a negative influence on the progress of the search, as in MOGA it is important to maintain the diversity during the search. In some cases, it may become difficult to obtain non-dominated solutions with high accuracy and diversity. To overcome this difficulty, whenever solutions are converged they are relocated evenly on an interpolated line.

However, it is very difficult to determine the parameters of these target solutions, as the target solutions exist in the objective field but not in the design field.