Efficient Test Point Selection using Multi-Objective Genetic Algorithms with Biological Kronecker Delta Evolution

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Abstract: In this paper, we propose a new approach of genetic algorithms to search for Pareto optimal solutions (i.e, non-dominated solutions) of TP (Test Point) selection problems. Our approach differs from other multi-objective genetic algorithms (MOGAs) in its evaluation mechanism and parameter settings.

Our genetic algorithm is using Biological Kronecker delta evolution which is two stage approaches. In the first stage, it optimizes the each single objective functions of the TP selection problem quickly using general single-objective genetic algorithms. In the second stage, it searches the Pareto optimal solutions using Biological Kronecker delta evaluation function and dynamic genetic operators.

We show the effectiveness of the suggested method by applying the suggested method to the TP selection of bio-nework processor designed in our group.

Ⅰ. INTRODUCTION

The selection of test point is one of the most essential steps in the hardware design and has large effects on the test cost and performance. In this paper, we propose a new systematic approach for the selection of test points in the hardware design.

To deal with the problem in a systematic way, we formulate the selection of the test points as knapsack-like optimization problem. The formulated test point (TP) selection problem becomes NP-complete and leads to a multi-objective optimization problem having three objectives.

Genetic algorithms (GAs) [1] have been successfully applied to various optimization problems. The extension of GAs to multi-objective optimization was proposed in several manners. In this paper we propose a new multi-objective genetic algorithms and applies it to the TP selection problem. The rest of this paper is organized as follows. Section Ⅱ explains basic MOGAs, TP selection problems and proposed algorithms. Section Ⅲ presents the results of experiments and relevant analysis. Section Ⅳ concludes this paper.

Ⅱ. EFFICIENT TP SELECTION USING MOGAs

2.1 Multi-Objective Genetic Algorithms

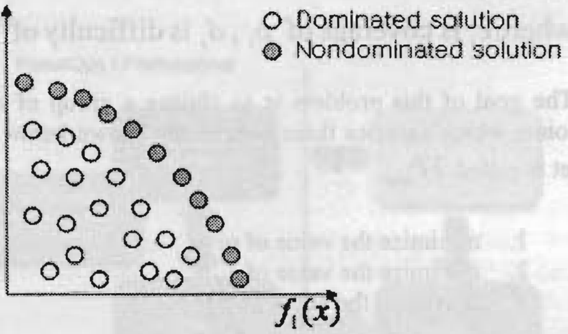

Fig. 1. Nondominated solutions and dominated solitions.

Genetic Algorithms have been mainly applied to single-objective optimization problems. Many real world problems, however, have multiple objective functions. These objective functions should be combined into a scalar fitness function in order to be handled by a single-objective genetic algorithm.

The aim of multi-objective optimization problems is to find all possible tradeoffs among multiple objective functions that are usually conflicting. Since it is difficult to choose a single solution for a multi-objective optimization problem without iterative interaction with decision maker, one general approach is to show the set of Pareto optimal solutions to the decision maker [2].

Let us consider the following multi-objective optimization problem with n objectives:

$$\text{Maximize } f_1(x), f_2(x), \cdots, f_n(x) \qquad (1)$$

where $f_1(x), f_2(x), \cdots, f_n(x)$ are n objectives to be maximized. When the following inequalities hold between two solutions x and y the solution y is said to dominate the solution x:

$$\forall_i : f_i(x) \le f_i(y) \text{ and } \exists_j : f_j(x) < f_j(y) \qquad (2)$$

If a solution is not dominated by any other solutions of the multi-objective optimization problem, that solution is said to be a nondominated(Pareto optimal) solution. Example of nondominated solutions are shown in Fig. 1

2.2 Test Point Selection Problem

Test point selection problem is an extension of the 0/1 knapsack problems. There is a set of n points to be tested:

$$TP = \{p_1, p_2, \cdots, p_n\} \tag{3}$$

where each point p_i has two components, coverage and difficulty. That is,

$$p_i = \{c_i, d_i\} \tag{4}$$

where c_i is coverage of p_i , d_i is difficulty of p_i

The goal of this problem is to choose a group of m test points which satisfies three constraints shown below. This set is called TP_{test}

1. minimize the value of m
2. minimize the value of C
3. maximize the value of M

$$\text{where} \quad C = \sum_{i=1}^{m} c_i' \ , \ \mathrm{D} = \sum_{i=1}^{m} d_i'$$

$$\mathrm{TP}_{\mathrm{test}} = \{p_1', p_2', \cdots, p_m'\} \ \text{ and } \ p_i' = \{c_i', d_i'\}$$

Therefore Test Point Selection problem is a three objective optimization problem. If the number of total test points n is large then it is somewhat troublesome to get solutions. So we apply MOGAs with biological kronecker delta evolution to this.

2.3 MOGAs with Biological Kronecker Delta Evolution

The proposed algorithms are MOGAs that find nondominated solutions. It consists of two stages. In the first stage, each single objective function of the TP selection problem is optimized using the standard single-objective genetic algorithms. In the second stage, it searches for the Pareto optimal solutions using the proposed biological Kronecker delta function and dynamic genetic operators.

We define a fitness function of proposed algorithms with n objectives by the following sum of the biological kronecker delta:

$$f(x_i) = \sum_{j=1}^{PopulationSize} \delta_{ij}$$

where δ_{ij} is the biological kronecker delta function

$$\delta_{ij} = \begin{cases} 1 & f_k(x_i) > f_k(x_j) \ \exists_k \text{ and } f_k(x_i) \geq f_k(x_j) \ \forall_k \\ 0 & \text{otherwise} \end{cases}$$

The biological Kronecker delta function is based on the Pareto ranking of individuals. It places the emphasis not on the fitness of objective functions but on the dominance of chromosomes unlike other multi-objective genetic algorithms (MOGAs). To preserve the Pareto optimal solution set we use the Elitist selection method and to prevent the converging local optimum we also use the ranking selection method.

Ⅲ. Simulation Results

In this section, we compare the proposed algorithms with the MOGA random search algorithms by T.Murata and H.Ishibuchi [2]. The number of total test points are 100 points, and the values of coverage and difficulty are random integer from 1 to 10. Fig.2 shows the pareto optimal solutions of two algorithms

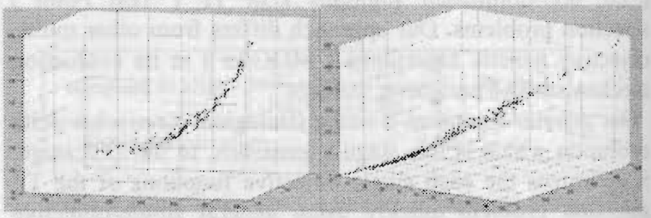

Fig.2. Pareto optimal solutions by random search(left) and proposed algorithm(right)

Total running time of proposed algorithms is a half of that of general MOGAs. The proposed method finds better solutions than random search method in TP Efficiency as shown in Table 1.

	Proposed method	General MOGAs
TP Efficiency	4.16	2.37

Table 1. value of TP Efficiency

In the Table 1 TP Efficiency is defined as (5)

$$TP\ Efficiency = \frac{Coverage - Difficulty}{number\ of\ test\ points} \tag{5}$$

Ⅳ. Conclusions

We propose novel technique for TP selection problem using MOGAs with biological kronecker delta function and describe its efficiency. The proposed method finds the solution set rapidly and extensively. The experimental result shows that the efficiency of the proposed method.

References

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