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Hybrid Genetic Algorithms with Conditional Local Search

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Abstract - Hybrid genetic algorithms (HGAs) have been studied as various ways. These HGAs usually use both the global search property of genetic algorithm (GA) and the local search one of local search techniques. One of the general types, when constructing HGAs, is to incorporate a local search technique into GA loop, and then the local search technique is repeated as many iteration number as the loop. This paper proposes a new HGA with a conditional local search technique (c-HGA) that does not be repeated as many iteration number as GA loop. For effectiveness of the proposed c-HGA, a conventional HGA and GA are also suggested, and then these algorithms are compared with each other in numerical examples.

1. INTRODUCTION

In general, HGAs are the coupling of two approaches: a GA and a local search one. These types of HGAs have been applied to various problems such as engineering optimization problems (Yun, Gen and Seo, 2003) and network design problems (Sinckair, 2000). In these previous approaches, the local search part of the HGAs was problem specific and was designed using trial-and error experimentation without generalization or analysis of the characteristics of the algorithm with respect to convergence and reliability (Espinoza, Minsker and Goldberg, 2001).

The purpose of this paper is to develop a new HGA with a conditional local search technique (c-HGA) that can be adaptively applied to GA loop with respect to the convergence property of GA. In Section 2, general types of GAs and local search techniques are considered when constructing HGAs, and then the main logic of the c-HGA is proposed. Section 3 shows the implementation strategy of the c-HGA. Numerical examples for comparing the c-HGA with conventional GA and HGA are tested and analyzed in Section 4. Finally some conclusion is followed in Section 5.

2. GENERAL TYPE OF HYBIRD GENETIC ALGORITHMS

In this Section, we first mention GA approach and local search one as a general type, and then suggest the concept of the HGAs with conditional and non-conditional local searches.

A. Genetic Algorithm Approach

The main role of GA approach, when constructing HGA, is to perform global search within all feasible search spaces. For this purpose, GAs have particular mechanisms for the global search: i) population-oriented search scheme for locating more various individuals, ii) three genetic operators (selection, crossover and mutation) for performing more various changes within population.

B. Local Search Approach

GA can do global search in entire space but there are no ways for local search around the convergence area generated by GA loop, thus GA is sometimes impossible or insufficient finding optimum in the problems requiring complex and precision values. To overcome this weakness, various methods for hybridizing GA using conventional local search techniques have been suggested. One of the common forms of hybridized GA is to incorporate a local search technique to a conventional GA loop. With this hybrid approach, local search technique is applied to each newly generated offspring to move it to a local optimum before injecting it into the new population (Gen and Chang, 1997).

In our approach, we incorporate the iterative hill climbing technique to GA loop (Michalewicz, 1994). Thus GA carries out global search and the iterative hill climbing carry out local search around the convergence area by GA loop. This technique can guarantee the desired properties of a local search technique for hybridization. The detailed procedure of the technique, for minimization problem, is given as follows:

Procedure: Iterative hill climbing technique in the GA loop
  begin
    select an optimum string v_c in current GA loop;
    randomly generate as many strings as the population size in the neighborhood of v_c;
    select the string v_n with the optimal value of the objective function f among the set of new strings;
    if $f(v_c) < f(v_n)$ then
    $v_c \leftarrow v_n$
    end
  end

C. HGA with Non-conditional Local Search (nc-HGA)

The nc-HGA is a standard type of HGAs and combines a GA with a local search technique. In this nc-HGA, the local search technique is performed as many generation number as the GA loop. Thus, the total iteration number in the nc-HGA loop becomes two times larger than that of the GA loop. The total running time of the nc-HGA may be also increased.

D. HGA with conditional local search (c-HGA)

The c-HGA works with the same operators as the nc-HGA. Major difference between the nc-HGA and c-HGA is that the c-HGA is adapted in response to recent performance as the approach converges to the optimal solution. For this scheme, we use the average fitness values from continuous two generations of GA loop, and then calculate the fitness value ratio (FVR) at the generations as follow:

$$FVR(t) = \frac{\overline{f_{new\_size(t)}}}{\overline{f_{new\_size(t-1)}}} \quad (1)$$

where $\overline{f_{new\_size(t)}}$: average fitness value of new population resulting from elitist selection strategy using parent and offspring sizes at generation t.

By this $FVR(t)$, the local search technique will be incorporated into GA loop conditionally. The adapting strategy for minimization problem is as follows:

$$\begin{cases} do \text{ GA with iterative hill climbing technique}, & if\ FVR(t) > 1 \\ do \text{ GA}, & \text{otherwise} \end{cases} \quad (2)$$

The adapting strategy of equation (2) means that the local search using the iterative hill climbing technique should be applied in GA loop to increase the locating chance of more respective offspring, if the average fitness value of current generation is not superior to that of the previous one. By this conditional scheme, HGA can automatically determine the use of local search during GA is converged to the optimal solution. Applying the conditional local search to GA loop is a main scheme of the c-HGA. Therefore, the total iteration number and running time of the c-HGA will be more decreased than those of the nc-HGA.

3. HGAS FOR EXPERIMENTAL COMPARISON

In this Section, we propose the detailed implementation procedure of the nc-HGA and c-HGA. First, for more various comparisons, the canonical GA procedure is presented, and then the procedures of two HGAs are proposed.

A. Canonical GA (CGA)

For the CGA, we use a real-number representation instead of a bit-string one, and the detailed heuristic procedure for its applying is as follows:

Step 1: Initial population
  Population by random number generation

Step 2: Genetic operators
  Crossover: uniform arithmetic crossover operator
  Mutation: uniform mutation operator
  Selection: elitist strategy in enlarged sampling space

Step 3: Stop condition
  If a pre-defined maximum generation number is

reached or an optimal solution is located during genetic search process, then stop; otherwise, go to Step 2.

B. nc-HGA and c-HGA

The procedure of the nc-HGA is to combine the CGA with the iterative hill climbing technique. Its combined heuristic procedure is as follows:

Steps 1-2: apply the same steps with the Steps 1 and 2 in the CGA loop.

Step 3: apply the iterative hill climbing technique suggested in sub-Section 2-C.

Step 4: apply the same step with the Step 4 in the CGA loop.

For the procedure of the c-HGA, we apply the iterative hill climbing technique proposed in sub-Section 2-D into Step 3 instead of that in sub-Section 2-C. Figure 1, for minimization problem, shows the flowchart of the c-HGA proposed in this paper.

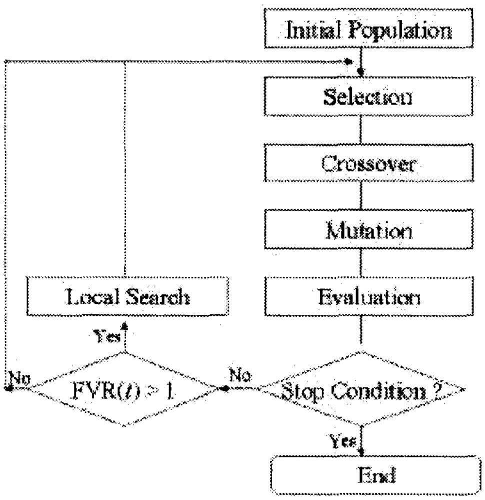

Figure 1. Flowchart of the c-HGA

4. NUMRICAL EXPERIMENTS

For evaluating the efficiency of the c-HGA, two test functions are presented as follows:

Test function 1(T-1): this is to minimize a function of two variables called the Rosenbrock function. This function is a De Jong's F2 (De Jong, 1975) and it has a global minimum of zero at $x_1 = x_2 = 1.0$, and each of x_1 and x_2 have the continuous values within the range -2.048 to +2.048.

$$f(x_1, x_2) = 100(x_1^2 - x_2)^2 + (1 - x_1)^2$$

Test function 2(T-2): this considers a function with five continuous variables, called the Rastrigin function (Hoffmeister and Bäck, 1991). It has a global minimum of zero at $x_1 = x_2 = x_3 = x_4 = x_5 = 0.0$, and all of the variales should be considered as continuous values within the range – 5.12 to +5.12.

$$f(x_1, x_2, x_3, x_4, x_5) = 15 + \sum_{i=1}^{5} (x_i^2 - 3\cos(2\pi x_i))$$

For the two test functions, the parameters of each algorithm (CGA, nc-HGA and c-HGA) are set as follows: maximum generation numer is 5,000, population size 20, crossover rate 0.5, mutation rate 0.05, search range for the iterative hill climbing technique 0.05. Alltogether 20 iterations are executed to eliminate the randomness of the searches in each algorithm. The results applied by each algorithm are listed in Table 1.

Table 1. Computational results for each algorithm

		Best	Average	NGS
T-1	CGA	0.000000	0.008675	10
	Nc-HGA	0.000000	0.000000	0
	c-HGA	0.000000	0.000000	0
T-2	CGA	0.000000	4.536445	19
	Nc-HGA	0.000000	0.001115	11
	c-HGA	0.000000	0.000805	8

In Table 1, "Best," "Average" and "NGS" mean the best fitness value, average fitness one and the number of getting stuck at a local optimum, respectively, after 20 iterations were executed.

For T-1, all the algorithms have located the optimal values in terms of the "Best." However, in "Average" and "NGS," the nc-HGA and c-HGA have shown same result, and they have outperformed the CGA. For T-2, the nc-HGA and c-HGA have shown significantly better performances than the CGA in "Average" and "NGS." Especially, the proposed c-

HGA has shown the best performance among all the algorithms. We have also analyzed the performances of local search between the nc-HGA and c-HGA. Figures 2 and 3 respectively show the average frequency ratio of local search and the average ratio of running time after 20 iterations were executed in T-1 and T-2, when we set the frequency ratio of the nc-HGA as 100%.

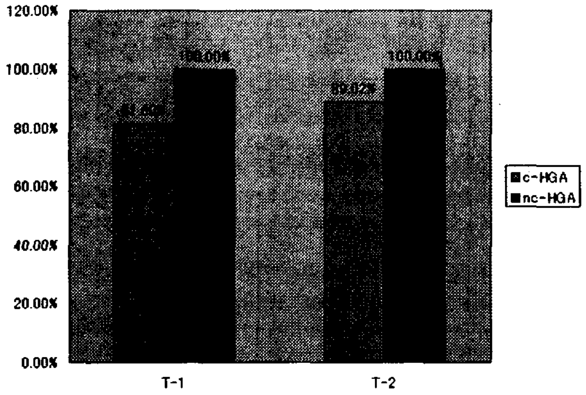

Figure 2. Average frequency ratio of local search

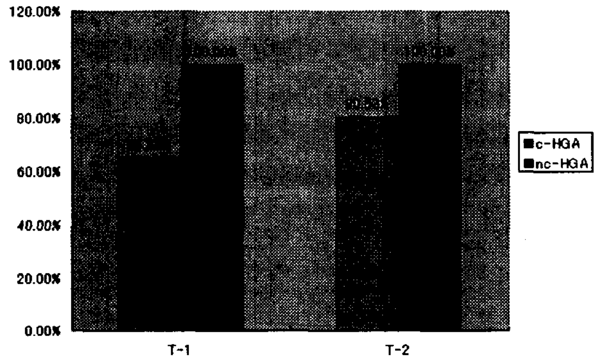

Figure 3. Average ratio of running time

In Figure 2, the ratios of the c-HGA are less 18.4% in T-1 and 10.98% in T-2 than those of the nc-HGA. This means that the local search in the c-HGA is conditionally applied to GA loop according to the values of $FVR(t)$, which implies that the running time of the c-HGA can be more reduced than that of the nc-HGA. Figure 3 proves this fact: the average ratios of the c-HGA are significantly less than those of the nc-HGA.

Based on the test results using T-1 and T-2, the proposed c-HGA is more efficient than the nc-HGA in the results of "Average" and "NGS" in Table 1 and those of Figures 2 and 3, even though the nc-HGA and c-HGA have same results in "Average" and "NGS" in T-1 of Table 1.

5. CONCLUSION

In this paper, we have proposed an efficient hybrid genetic algorithm with conditional local search scheme (c-HGA). The proposed c-HGA adapts local search conditionally according to the change of the fitness value ratios during genetic search process. In numerical examples, two test functions have been used for evaluating the efficiency of the c-HGA. By various comparisons with other competing algorithms, the efficiency of the c-HGA has been proved.

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