NCGA:Neighborhood Cultivation Genetic Algorithm for Multi-Objective Optimization Problems

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Genetic Algorithm for Multi-objective Optimization

Multi-objective optimization problem

In the optimization problems, when there are several objective functions, the problems are called the Multi-objective or Multi-criterion Optimization Problems (MOPs).
The multi objective optimization problems are formulated as follows. In general,

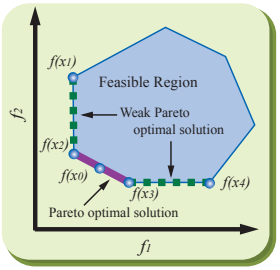
$$\begin{cases} minimize & \boldsymbol{f}(\boldsymbol{x}) = (f_1(\boldsymbol{x}), f_2(\boldsymbol{x}), \cdots, f_k(\boldsymbol{x}))^T \\ subject\ to & \boldsymbol{x} \in \boldsymbol{X} = \{\boldsymbol{x}\} \in R^n \mid g_i(\boldsymbol{x} < 0,\ j=1, \cdots, m)\} \end{cases}$$

$$\begin{cases} f_i(\boldsymbol{x}) = f_i(x_1, x_2, \cdots, x_n),\ i=1, \cdots, k \\ g_j(\boldsymbol{x}) = g_j(x_1, x_2, \cdots, x_n),\ j=1, \cdots, m \end{cases}$$

X is the domain that satisfies the constraints and is called the feasible domain.

Pareto-optimum solution

When $x^1 \in X$ and $x^2 \in X$ satisfy $f_i(x^1) < f_2(x^2)$ for all of the objective functions and f_i and satisfy $f_i(x^1) < f_2(x^2)$ for some of the objective functions $f_i(x^1)$ is



Multi-objective GA

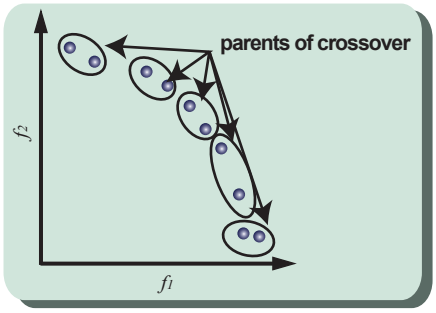
In multi-objective optimization, GA can find a Pareto-optimum set with one trial because GA is a multi point search. As a result, GA is a very effective tool especially in multi-objective optimization problems. Thus, there are many researchers who are working on multi-objective GA.
These algorithms of multi-objective GA are roughly divided into two categories; the algorithms that treat Pareto-optimum solution implicitly or explicitly.

Neighborhood Cultivation Genetic Algorithm (NCGA)

We develop a new algorithm that is called Neighborhood Cultivation Genetic Algorithm (NCGA). NCGA has a neighborhood crossover mechanism in addition to the mechanisms of GAs that had proposed in the past researches. The following mechanisms are included in NCGA.

- Preservation mechanism of the excellent solutions
- Reflection mechanism of the preserved excellent solutions
- Cut down (sharing) method of the preserved excellent solutions
- Assignment method of fitness function
- Normalization mechanism of values of each object

In NCGA, the exploitation factor of the crossover is reinforced. In the crossover operation of NCGA, a pair of the individuals for crossover is not chosen randomly, but individuals who are close each other are chosen. This crossover is **neighborhood crossover**.



In NCGA, most of the genetic operations are performed in a group that is consisted of two individuals. That is why this algorithm is called "neighborhood cultivation".

Numerical Examples

In this section, **NCGA** is applied to the some test functions. The results are compared with those of **SPEA2**, **NSGA-II** and **non-NCGA (nNCGA)**. nNCGA is the same algorithm of NCGA except neighborhood crossover.

Test Functions

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$$\begin{cases} \text{Min } f_1(\boldsymbol{x}) = \sum(-10 \exp(-0.2\sqrt{x_i^2 + x_{i+1}^2})) \\ \text{Min } f_2(\boldsymbol{x}) = \sum(|x_i|^{0.8} + 5\sin(x_i)^3) \end{cases}$$

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$$\text{Max } f_i(\boldsymbol{x}) = \sum p_{ij} \cdot x_j$$

$$\text{subject to } \sum w_{ij} \cdot x_j \leqq c_j$$

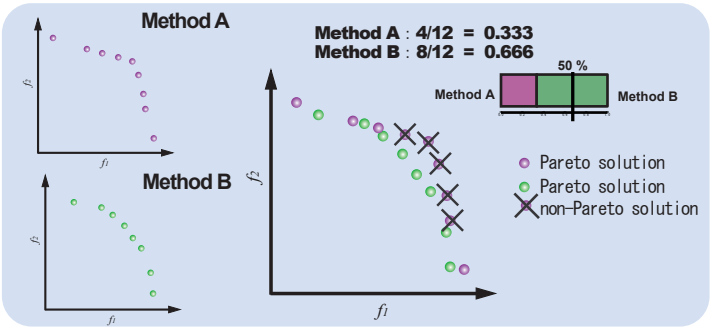
p_{ij} = profit of item j according to knapsack i
w_{ij} = weight of item j according to knapsack i
c_i = capacity of knapsack i

Evaluation methods

To compare the results derived by each algorithm, the following evaluation methods are used in this examples.

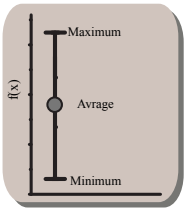
Ratio of Non-dominated Individuals (RNI)

This performance measure is derived from comparing two solutions which are derived by two methods. By RNI, the accuracy of the solutions can be compared.



Maximum, Minimum and Average values of each object of derived solutions (MMA)

To evaluate the derived solutions, not only the accuracy but also the expanse of the solutions is important. To discuss the expanse of the solutions, the maximum, minimum and average values of each object are considered.



Results

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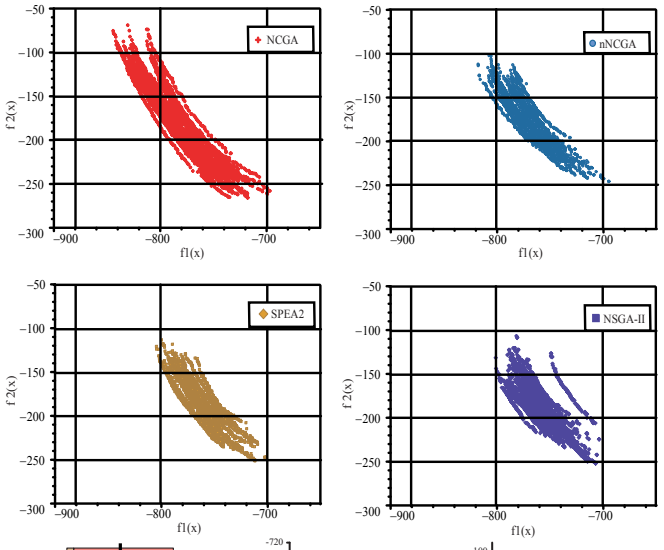

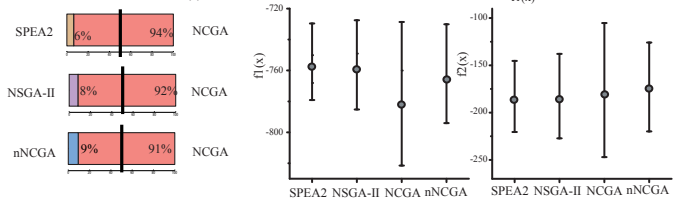

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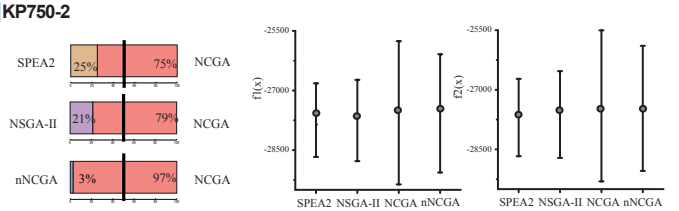

Conclution

The proposed algorithm, Neighborhood Cultivation Genetic Algorithm (NCGA), has not only important mechanism of the other methods but also the mechanism of neighborhood crossover selection. To discuss the effectiveness of the proposed method, NCGA was applied to test functions and results were compared to the other methods.
Through the numerical examples, the following topics are made clear.

- In almost all the test functions, NCGA derived the good results.
- Comparing to NCGA using neighborhood crossover and NCGA using random crossover, the former is obviously superior to the latter in all problems.

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