A Novel Genetic Algorithm based on the Life Cycle of Dictyostelium

Kazuyuki Inoue
Graduate school of Engineering Osaka Prefecture University
1-1 Gakuencho, Sakai city
Osaka 599-8531,JAPAN
inoue@ss.cs.osakafu-u.ac.jp

Naoki Mori
Graduate school of Engineering Osaka Prefecture University
1-1 Gakuencho, Sakai city
Osaka 599-8531,JAPAN
mori@cs.osakafu-u.ac.jp

Matsumoto Keinosuke
Graduate school of Engineering Osaka Prefecture University
1-1 Gakuencho, Sakai city
Osaka 599-8531,JAPAN
matsu@cs.osakafu-u.ac.jp

ABSTRACT

We have proposed the novel evolutionary computation called "Dictyostelium based Genetic Algorithm" (DGA), which adopts the concept of life cycle of slime molds and can take a balance between exploitation and exploration.

In this research, we propose an extension of DGA with an index evaluating population diversity. To analyze the abilities of DGAs, the computational experiments are carried out taking several combinatorial optimization problems as examples. We show that the performance of DGAs is superior to that of Simple GA in all examples.

Categories and Subject Descriptors

I.2.8 [ARTIFICIAL INTELLIGENCE]: Problem Solving, Control Methods, and Search

General Terms

Algorithms

Keywords

Combinatorial optimization, Dictyostelium, Fitness landscapes, Genetic Algorithm, Local search

1. INTRODUCTION

We have proposed the novel method called "Dictyostelium based Genetic Algorithm" (DGA) which introduces the life cycle dynamics of dictyostelium into GA search. DGA is part of "Genetic Local Search" (GLS) by adopting the life cycle dynamics of dictyostelium to balance between the dynamics of global search and local search.

In this paper, we propose the modified DGA using two novel indices, "density size" and "P-I similarity index" giving a guideline for controlling diversity and local search. We also show several results of comparison studies taking combinatorial optimization problems as examples. The search performance of modified DGA is drastically improved by introducing a controlling method of local search and diversity.

2. INDICES FOR INDIVIDUAL'S DISTRIBUTION

DGAs utilize two main indices for measuring individual's distribution called "density size" and "P-I similarity index".

2.1 Density size

The density size N_s is one of the crowdedness index of the individual s. N_s is the number of individuals with genotype s in the population. The distribution of density size in population strongly depends on the selection pressure.

2.2 P-I similarity index

We propose P-I similarity index $R(s, X)$ to evaluate similarity between individual s and population X based on the Nei's standard genetic distances[1]. P-I similarity index is represented by the following equations:

$$R(s,X) = \frac{\frac{1}{L}\sum_{i=0}^{L-1}(2x_{is_i}-1)}{\sqrt{\frac{1}{L}\sum_{i=0}^{L-1}(2x_{is_i}-1)^2}} \quad (1)$$

where s_i is gene of s on locus i and x_{is_i} represents the ratio of gene s_i in population X.

If the index value is near to 1, the individual s has a strong positive correlation with population X. On the other hand, if the index value is near to 0, the individual s has almost no correlation with population X. If we pick up the s from GA population X, the index of individual s and population X becomes almost 0 in an early stage of searching and increases to 1 in a late stage of searching.

3. DICTYOSTELIUM BASED GENETIC ALGORITHM

3.1 Outline of DGA

Dictyostelium is the most popular cellular slime mold. The shape of dictyostelium is very interesting and stimulating. The first shape of dictyostelium is amoebae, then they aggregate to change their form called "slug" when the surrounding of amoebae becomes worse. Slugs can move to

GECCO'14, July 12–16, 2014, Vancouver, BC, Canada.
ACM 978-1-4503-2881-4/14/07.
http://dx.doi.org/10.1145/2598394.2598469.

Table 1: Performance of each algorithm

problems (number of evaluations)	applied GAs														
	SGA			GLS			TDGA			DGA(simple)			DGA(P-I)		
	average	min	success	average	min	success	average	min	success	average	min	success	average	min	success
deceptive 90 (100000)	29.881	29.3	43	29.901	29.4	42	29.933	29.7	49	29.930	29.5	51	29.977	29.8	80
$Nk, N = 30, k = 6$(50000)	0.8110	0.7669	73	0.8165	0.7792	87	0.8114	0.7724	53	0.8185	0.8185	100	0.8185	0.8185	100
knapsack 100 (100000)	11876.6	11858	79	11877.0	11869	68	11877.9	11876	99	11877.8	11871	91	11877.9	11872	95

other places to get enough nutrition and suitable surrounding. After the movement, slugs spread spores and each spore germinates in this new environment as an amoeba.

"Dictyostelium based Genetic Algorithm" (DGA) is an extended GA. DGA has two novel genetic operators based on the life cycle dynamics of dictyostelium called "Movement" operator and "Spread" operator. In DGA we should tune three parameters called "density threshold A", "movement rate α" and "spread radius d". Threshold A controls the condition of making slug, movement rate α controls the weight of movement operator and spread radius d controls the work of spread operator.

3.2 Definition of slug

The condition of making a slug depends on the genotype density size N_s as mentioned in 2.1 and "density threshold" A. Only groups of individuals with density size $N_s \geq A$ can change to one slug.

3.3 Genetic operators in DGA

DGA has two search parts called "GA part" and "Slug part". The genetic operators in GA part are the same operators with conventional GA, crossover, mutation and selection. These operators are applied to all individuals. Slug part utilizes two novel operators called movement operator and spread operator. In contrast to GA part, the operators in slug part are only applied to slugs.

3.3.1 Movement operator

Movement operator in DGA is a local search method applying only for slug. The number of local search of slug s is T_s. T_s represents the maximum number of fitness evaluations that the slug s can use. Then the slug s continues to execute local search until the number of fitness evaluations consumed by slug s approaches T_s or the slug s has no candidates of solutions to renew in its neighborhood. The value of T_s is described in the next section.

3.3.2 Spread operator

Spread operator produces new individuals isotropic randomly in the hyper sphere of genotype space centered at slug genotype. We define h_s called "spread distance" as the hamming distance between a new individual and the slug s described in the next section.

While N-1 individuals take their genotype from the spread operator, one individual always keeps the genotype of the original slug.

4. PROPOSED METHOD

In simple DGA, the number of local search T_s in movement operator is defined as equation (2), and the spread distance h_s in spread operator is defined as equation (3).

$$T_s = [\alpha N_s] \tag{2}$$

$$h_s = [\ |z + d| + 0.5\ ] \tag{3}$$

We proposed modified T_s and h_s as following equations, utilizing P-I similarity index $R(s, X)$ in section 2.2.

$$T_s = [(1 - R(s, X))\alpha N_s] \tag{4}$$

$$h_s = [\ |z + R(s, X)dN_s| + 0.5\ ]H_0(R(s, X)d) \tag{5}$$

where s represents a slug, z is standard Gaussian random variable, X represents current population in GAs searching, $H_0(x)$ represents Heaviside-step function except $H_0(0) = 0$. $R(s, X)$ is calculated by regarding the genotype of slug s as one individual. These new movement operator and spread operator can change their own behavior adaptively according to P-I similarity index $R(s, X)$.

We call the DGA using equation (2) and (3) "DGA(simple)" and the DGA using equation (4) and (5) "DGA(P-I)".

5. EXPERIMENTS

In this experiments, we used SGA, DGA(simple), DGA(P-I), the conventional GLS which executed local search to population uniformly and TDGA[2] which had a characteristic of control of diversity as comparison studies. We set the parameters of these methods to adequate value by a preparatory experiment. To analyze the performance of DGAs, we compared the average fitness, the minimum fitness and the successful runs (i.e. found optimal solution) in all trials.

Table 1 shows the performance of each algorithm. From Table 1, DGAs show better performance than SGA in any kind of problems. Especially, the search performance of proposed DGA(P-I) was remarkably improved in deceptive problem 90. Moreover the best parameters in deceptive problem 90 included the movement rate $\alpha = 10$ and density threshold $A = 2$. The DGA(P-I) with such parameters frequently executes local search. The GLS with traditional local search applied to all individuals uniformly is not effective for deceptive problem, however the best result of DGA(P-I) indicates that local search becomes effective even for deceptive problem with control the number of local search adjusting to the individual state.

This work was supported by JSPS KAKENHI Grant, Grant-in-Aid for Scientific Research(C), 2500208, 2010-2013

6. REFERENCES

[1] Y. Katada, K. Ohkura and K. Ueda: Measuring Neutrality of Fitness Landscapes Based on the Nei's Standard Genetic Distance, Proceedings of 2003 Asia Pacific Symposium on Intelligent and Evolutionary Systems, Technology and Applications, pp.107-114 (2003)

[2] N. Mori and H. Kita: The entropy evaluation method for the thermodynamical selection rule, In Proceedings of the 5th the Genetic and Evolutionary Computation Conference , pp 799 (1999)