A Novel Cloud Evolutionary Strategy for Ackley's Function

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Abstract. This paper proposes a novel evolutionary strategy based on cloud model, and applies it to solving the well-known multi-modal Ackley’s problem. The results indicate that cloud evolutionary strategy is better than standard genetic algorithm or a kind of optimization algorithm based on the genetic algorithm and nonlinear programming in the convergence speed and search accuracy.

Introduction

In the cloud model [1, 2], which is a new cognitive model for uncertain transformation between linguistic concepts and quantitative values, we employ the expectation (Ex), the entropy (En), and the hyper-entropy (He) to represent the concept as a whole. Especially, the normal cloud model can avoid the flaw of fuzzy sets to quantify the membership degree of an element as an accurate value between 0 and 1, therefore, may be more adaptive for the uncertainty description of linguistic concepts.

The cloud evolutionary strategy (CES) is a novel rapid evolutionary algorithm based on the outstanding characteristics of the cloud model on the process of transforming a qualitative concept to a set of quantitative numerical values [3, 4].

The paper is constructed as follows: Section II detailed describes the realization process of the cloud evolutionary strategy. Section III introduces the Ackley’s problem [5-9]. Finally, we apply the novel approach to solving the well-known multi-modal problem. The simulation results indicate that cloud evolutionary strategy is better than standard genetic algorithm (SGA) or a kind of optimization algorithm based on the genetic algorithm and nonlinear programming (GANP) [10] in the convergence speed and search accuracy.

Cloud Evolutionary Strategy

Combined with the basic principle of evolutionary strategy, three numerical characteristics of cloud model can be used to overall control the evolution course of a “species”, then we put forward a novel cloud evolution strategy.

In the cloud evolution strategy, the Ex called seed individual, expresses the excellent characteristics of ancestral inheritance; the En called variation entropy, represents the evolution scope; the He called variation hyper entropy, reflects the stability of evolution. Generally speaking, the more He/En, the greater the uncertainty of evolution. The initial value of En should be larger, usually 1/3 of the solving range. The initial value of He has bigger influence
on individual discrete degree, usually set to 0.05 En. Given Ex as parent body, specified the
 evolution parameters En and He, positive cloud generator can generate any number of cloud
droplets, which satisfy the constraints are the offspring of the parent individual.

All individuals (the total number is n) of every evolutionary generation form a community,
which divided into m populations, referred to as community richness. The populations scale PS= (k_1,k_2,...,k_m). Offsprings of different populations are generated by excellent individuals
from the last generation. The population size is different depending on the fitness of parent
body. The selection mechanism embodies the idea of survival of the fittest in evolutionary
theory.

Contemporary elite is the most adaptable individual of an evolutionary generation. Across
generations elite is the most adaptable individual of multiple generations. The generation is
called non-trivial evolutionary generation when across generations elite appears, otherwise
called ordinary evolution generation. The number of generations between two neighbouring
across generations elites is called continuous ordinary number.

Mutation strategy refers to the control strategy of mutation in the process of evolution. By
adjusting the parameters En and He/En, we can solve two problems: the first is the local
refinement, when across generations elite turns up, we should reduce En and He/En to 1/ K
of the original, thus increase the accuracy and stability of the search in order to achieve the
purpose of rapid local refinement. The last is local change, as several evolutionary generations
have not found a new across generations elite, i.e., continuous ordinary number reaches a
certain threshold λ, the algorithm could fall into a local optimal neighborhood, it need to
increase En and He/En by L times.

Like most of the process of evolutionary computation method, the basic steps of CES are as
follows.

Step 1: set the initial parameters {n, m, PS, Ex, En, He, λ, K, L, G}.
Step 2: use forward normal cloud CG (Ex, En, He, n) to generate n cloud drops as the initial
community.
Step 3: calculate the fitness of all individuals, and choose out of the top m as the
contemporary optimal individuals.
Step 4: use forward normal cloud and the m contemporary optimal individuals to create a
new community, update the contemporary community.
Step 5: If reach the evolutionary generations G, algorithm stops, the contemporary elite is the
optimal solution, otherwise go to step 3.

Ackley’s Function

Acknowledgements was first published in [5] by D.H. Ackley, and was extended to arbitrary
dimension in [6] by T. Back. The Ackley’s problem consists in determining the optimal design
of an exponentially decaying energy storage problem, in order to store a significant amount of
many small hills and valleys on the broad exponential mountain. The collecting area of the
global maximum is small, and an iterated hill climber will get stuck on one of the hilltops most
of the time [5]. The Ackley function is widely used for testing optimization algorithms.

The Ackley’s problem is a minimization problem. Formally, this problem can be described
as finding a string \( \vec{x} = (x_1, x_2, \ldots, x_n) \), with \( x_i \in (-32.768, 32.768) \), that minimizes the following
equation:
\[ f(\vec{x}) = -c_1 \cdot \exp \left( -c_2 \sqrt{\frac{1}{n} \sum_{i=1}^{n} x_i^2} \right) - \exp \left( \frac{1}{n} \sum_{i=1}^{n} \cos \left( c_3 \cdot x_i \right) \right) + c_4 + \epsilon \]

Where \( c_1 = 20 \), \( c_2 = 0.2 \), and \( c_3 = 2\pi \). Also, \( n \) is the number of dimensions. In this paper, we only consider \( n = 2 \). The 2 dimensions Ackley’s function is illustrated in Fig. 1, which is characterized by a nearly flat outer region, and a large hole at the center. The minimum of Ackley function is 0 that occurs at the origin.

![Figure 1. Two-dimensional Ackley’s Function.](image)

**Optimization Results and Analyses**

Y. Lei et al. [10] proposed a kind of optimization algorithm based on the genetic algorithm and nonlinear programming. This method combined with nonlinear programming ideas, can improve the search performance of standard genetic algorithm, but the rate of convergence is also not significant.

For the sake of comparing and analysing, set the total number of individuals of each generation \( n = 20 \), community richness \( m = 10 \), the populations scale \( PS = (6, 4, 3, 1, 1, 1, 1, 1, 1, 1) \), \( \lambda = 3 \), \( K = 4 \), \( L = 2 \), and evolutionary generations \( G = 30 \).

The convergence performance of three algorithms can be seen from Fig. 2 (a) to (c). It is obvious that CES shows comprehensive performance for Ackley’s problem. CES is better than others in the convergence speed and search accuracy, as shown in Fig. 1 and Table 1.

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<th>Table 1 CES Optimization Results Compared with SGA and GANP.</th>
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Figure 2. Comparisons of Convergence Performance among SGA, GANP and CES.

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