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A hybrid global optimization algorithm based on parallel chaos optimization and outlook algorithm

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ABSTRACT

Based on the analysis of the properties of tent map, parallel chaos optimization algorithm (PCOA) using logistic map and outlook algorithm, a hybrid global optimization algorithm (PCOOA) is presented. The algorithm is structured in two stages. The first stage uses parallel chaos optimization based on tent map for global search, while outlook algorithm is employed in the second stage for local search. The simulation results show that the algorithm, with high rate of convergence, optimization efficiency and strong robustness etc., is an effective technique to solve nonlinear programming (NLP) problems.

Keywords: parallel chaos optimization; outlook algorithm; global optimization; tent map

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INTRODUCTION

Chaos is a universal phenomenon existing in many systems in all areas of science [1]. It has three important dynamic properties: the intrinsic stochastic property, ergodicity and regularity [2]. A chaotic movement can go through every state in a certain area according to its own regularity, and every state is obtained only one. Taking advantage of chaos, a new searching algorithm called chaos optimization algorithm (COA) is presented [3]. It can more easily escape from local minima compared with the exiting stochastic searching algorithm. However, the COA has the shortage of the sensitive dependence on initial condition, tiny difference in initial value, there may be carrying completely searching process. Some states may be reached costing longer time. Therefore, the search time will be very long, if the global optimal solution appears nicely in these states. Parallel chaos optimization algorithm was proposed to solve this problem by searching synchronously from several initial points [4].Whereas, further research show that this method has the lower searching efficiency near the optimum point owing to stochastic property of chaotic movement [5].

Outlook algorithm is proposed according to common knowledge that one decides the highest point of mountains by outlook. It can solve global optimization problem by employing supervision mechanism of outlook, strategies of generating outlook points and mechanisms of constructing and solving local problems [6]. Outlook algorithm has high rate of convergence, fast search velocity and strong robustness, etc.

In this paper, we propose a hybrid algorithm based on PCOA and outlook algorithm. The algorithm is structured in two stages. The first stage uses parallel chaos optimization based on tent map for global search. To accelerate local convergence and rapidly generate an exact solution, outlook optimization algorithm is subsequently employed in the second stage. The simulation results show that the algorithm is more effective than PCOA.

This paper is organized as follows. Section II formulates nonlinear programming problem. Section III summarizes firstly PCOA and outlook algorithm, then presents the hybrid global optimization algorithm based on PCOA and outlook algorithm. In Section IV, some examples are tested by the proposed method and the results are compared with PCOA.. Conclusions in Section V close the paper.

EXPERIMENTAL SECTION

Problem formulation

A NLP problem with inequality constraints is a problem that can be put into the form:

minimize $f(x)$

sbuject to $g_i(x) \le 0, i = 1, 2, \cdots, m$

$x_i \in [a_i, b_i], i = 1, 2, \cdots, n$

Where x is a vector of n component $x_1, \cdots, x_n$, $f(x)$ is the objective function and $g_i(x)$ is the inequality constraints.

Hybrid global optimization algorithm

A. PCOA

PCOA was proposed by Liang [4]. Its main idea is searching the solution space by different several group chaos sequences. Firstly, use the carrier wave method to make optimization variables vary to chaos variables. Secondly, amplify the ergodic area of chaotic motion to the variation ranges of every controllable variable. Finally, use the chaos search method to optimization problem. The method is summarized as following:

1) Initialization.

Set $n = 1$,

$x_{(i,j,n+1)} = 4 * x_{(i,j,n)} * (1 - x_{(i,j,n)})$

Where $i = 1, \cdots, p$, represents the different initial starting points of i classes, $j = 1, \cdots, N$, expresses the variable number included in the optimized problem, n is the interation times.

2) Carrying out the first carrier wave. The chaos variables are imported into the optimized variables, moreover, the change range of the chaos variables are separately amplified the corresponding value range of optimized variables.

$x'_{(i,j,n+1)} = c_{(i,j)} + d_{(i,j)} * x_{(i,j,n+1)}$

Where $x_{(i,j,n+1)}$ is chaos variable, $c_{(i,j)}$ and $d_{(i,j)}$ are constants, $x'_{(i,j,n+1)}$ is variable used for optimized problem.

3) Carrying out iteration search. In each generation, set the optimal solution of all classes as the current solution. If no better solution is found after N searches, the second carrier wave will be executed according to the following equation:

$x''_{(j,n+1)} = x^*_j + \alpha * x_{(j,n+1)}$

Where x^*_j is the current solution, α is regulation constant, $x_{(j,n+1)}$ is chaos variable.

4) Performing iteration search. If no better solution is found after M searches, stoping search and output current optimal solution.

B. Outlook algorithm

Outlook algorithm was proposed by Cai [6]. It is composed by three parts: supervision mechanism of outlook, strategies of generating outlook points and mechanisms of constructing and solving local problems. It can solve global optimization problem according to the following route:

1) Conforming basic point by supervision mechanism of outlook;
2) Generating outlook point of base point by strategies of generating outlook points;
3) Choosing outlook point according to given standard by supervision mechanism of outlook;
4) Constructing the local problem of outlook point and solving it by local optimization algorithm;
5) After getting all the solutions of local problems chosen, conforming next base point and begin a new iteration until satisfying end condition and put out solution.

C. Chaos variables

Tent map has better ergodicity uniformity than logistic map, so the COA based on tent map has better optimization efficiency [6]. In addition, tent map has simple structure and interation process is fit for computing by computer [7]. In this paper chaos variables are generated by tent map. The tent map is defined by:

$$\gamma(k+1)=\begin{cases}2\gamma(k) & 0\le\gamma(k)\le 1/2\\ 2(1-\gamma(k)), & 1/2<\gamma(k)\le 1\end{cases} \tag{1}$$

After shift transforming, it can be expressed as the following equation:

$$\gamma(k+1)=(2\gamma(k)) \bmod 1 \tag{2}$$

Its output is like a stochastic output, no value of $\gamma(k)$ is repeated and the deterministic equation is sensitive to initial conditions. Those are the basic characteristics of chaos. Moreover, the essential of carrying out tent map by computer is left shift without symbol about binary digit of decimal fraction. This operation use adequately computer's characteristic and more suits for large magnitude data sequence.

D. Proposed algorithm

First, using PCOA based on tent map for global search. It is easy to reach the area near global optimization solution owing to the ergodicity. However, local searching speed become very slowly and it is difficult to get the high precision optimization solution due to the stochastic property of algorithm. Thus the outlook optimization algorithm is employed in the second stage for local search. High searching efficiency is obtained after uniting PCOA with outlook algorithm. The method is presented as following:

Step *1)* Initialize chaos variable $\gamma_j^i(0)$, $0\le\gamma_j^i(0)\le 1$, $(i=1,2,\cdots,n \;\; j=1,2,\cdots,p)$, by means of stochastic way, which have small differences. There will generate $p\times n$ chaos variables having different track. The positive integers $N1$, $N2$ are specified. Let $flag=1$, $C=0$, $k=0$; where $flag$ is outlook symbol, C is base point counter, k is iteration times.

Step *2)* Chaos variable $\gamma_j^i(0)$ is mapped into the variance ranges of optimization variables by the following equation:

$$x_j^i(0)=a_i+\gamma_j^i(0)(b_i-a_i)$$
$$(i=1,2,\cdots,n \;\; j=1,2,\cdots,p) \tag{3}$$

Let $f_j^*=f(X_j(0)),\ X_j^*=X_j(0),\ f^*=\min(f_j^*),\ X^*=X_j^*$,

where X_j^* is the best solution of the j team, X^* is the global best solution.

Step *3)* Carry out chaos search by using the carrier wave:

Repeat

$$\gamma_j^i(k+1)=(2\gamma_j^i(k)) \bmod 1$$

$x_j^i(k+1) = a_i + (b_i - a_i)\gamma_j^i(k+1)$
$(i = 1,2,\cdots,n \;\; j = 1,2,\cdots,p)$
If $f(X_j(k+1)) < f_j^*$,
Then $X_j^* = X_j(k+1),\; f_j^* = f(X_j(k+1))$
Else if $f(X_j(k+1)) \geq f_j^*$,
Then give up $X_j(k+1)$
If $\min f_j^* < f^*$,
Then $f^* = f_j^*, X^* = X_j^*$
Else do nothing.
Let $k \leftarrow k+1$
until f^* does not improve after $N1$ searches.

Step *4)* Set $X^B = X^*$, where X^B is outlook base point.
Step *5)* If $flag = 1$ and $C < N2$

Then carry out Step 6)
Else go to step 7).

Step *6)* Generating outlook point of base point X_i^o $(i = 1,2,\cdots,m)$ according to strategies of generating outlook points provided by paper [6] (this paper use strategies of generating outlook points based on square body).
Step *7)* While $f(X_i^o) \leq f(X^B)$

Carry out local search and get local optimum solution X_i^l from the point X_i^o.The search strategies can use local search method such as simplex search, gradient search etc.
If $\min f(X_i^l) < f(X^B)$,

Then $X^B = X_i^l$, $flag = 1$, return to step *7)*.
Else carry out step *8)*.
Step *8)* Stop the search process and put out $X^* = X^B$ as the best solution, $f^* = f(X^B)$ as the best value.

RESULTS AND DISCUSSION

Test functions

To evaluate the efficiency and effectiveness of the algorithm for nonlinear programming problems, we choose the following four complex test functions for simulation. These functions entrap into local optimum easily. There are numerous local optima around the global optimum. The optimal solution and exact optimum of functions in theory is shown in Table-1.

$$F1: \min f(X) = 100(x_1^2 - x_2)^2 + (1 - x_1)^2,$$
$$-2.048 \leq x_i \leq 2.048, \quad i = 1,2$$
$$F2: \min f(X) = [1 + (x_1 + x_2 + 1)^2(19 - 14x_2 + 6x_1x_2$$
$$+ 3x_2^2)] \times [30 + (2x_1 - 3x_2)^2(18 - 32x_1 + 12x_1^2 + 48x_2$$
$$- 36x_1x_2 + 27x_2^2)]$$
$$-2 \leq x_i \leq 2, \; i = 1,2$$

$$F3: \min\ f(X) = (4 - 2.1x_1^2 + x_1^4/3)x_1^2 + x_1x_2 + (-4 + 4x_2^2)x_2^2$$

$$-2 \le x_i \le 2,\ \ i = 1, 2$$

$$F4: \min\ f(X) = 0.5 - \frac{\sin^2\sqrt{x_1^2 + x_2^2} - 0.5}{(1 + 0.001(x_1^2 + x_2^2))^2},$$

$$-4 \le x_i \le 4,\quad i = 1, 2$$

Table-1 The optimal solution and exact optimum of functions in theory

	F1	F2	F3	F4
OPT. SOLUTION	(1, 1)	(0, -1)	(-0.0898,0.7126) (0.0898,-0.7126)	(0, 0)
EXACT OPT.	0	3	-1.0316	-1

Numerical results

This paper computes separately the above four test functions 100 runs using the proposed method (PCOOA) and PCOA [2].The platform used is a AMD 2.19GHz PC. The convergence rate of two algorithm are shown in table-2, the average iteration time is shown in table-3, the average computing time of finding the optimum is shown in table-4.

Table-2 Convergence rate of two algorithms

Algorithm	Convergence rate (%)			
	F1	F2	F3	F4
PCOA	100	100	100	100
PCOOA	100	100	100	100

The data of table-2 show that both of the PCOA and the PCOOA can find the global optimal solutions as convergence rate 1.

Table-3 Iteration times of two algorithms

Algorithm	Iteration times			
	F1	F2	F3	F4
PCOA	2906	8415	5617	2636
PCOOA	595	575	968	1085

Table-4 Computing time of two algorithms

algorithm	Computing time (sec)			
	F1	F2	F3	F4
PCOA	13.24	13.92	10.26	42.3
PCOOA	2.96	7.06	8.24	16.7

The data of Table-3 and Table-4 show that the PCOOA uses less time and fewer interation times than PCOA for finding the global optimum solutions of NLP. It is apparent that the proposed algorithm is superior to PCOA in computing time and searching efficiency.

CONCLUSION

This paper proposed a hybrid algorithm based on parallel chaos optimization and outlook algorithm for solving NLP problems. PCOA performs a global search in the first stage. To accelerate local convergence in the second stage, the outlook algorithm is subsequently adopted in the second stage. A comparative study between the hybrid algorithm and PCOA is conducted. The results show that the hybrid algorithm with high rate of convergence and search efficiency, is an effective method to solve NLP problems.

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