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Taboo Niche Optimization Based on Intelligent Engineering and Its Application in Water Ecology

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Abstract: -- Intelligent Engineering is kind of method incorporating artificial intelligence Neuron Network and fuzzy system and is of superiority in solving complex system concerning multiple factors. Niche Taboo optimization algorithm is good at solving non-linear optimization problem. In the paper, Intelligent Engineering is used for description of system states and providing a framework for complex problem solving while Taboo Niche optimization algorithm is used for optimization path search in the state-space of intelligent space. The paper details the main idea of Intelligent Engineering and the algorithm of Niche Taboo optimization. Finally a simple case study for water ecology developmental strategy is given to show the feasibility of the method proposed.

Key-words: Intelligent Engineering, Niche Taboo Optimization, Algorithm, Water Ecology

1. Introduction

From scientific research and engineering design, to operation research, for the problem interested, some descriptions and definitions can be given. However the factors describing the state of the system involving multiple domains of social, ecological and economic, etc., lots of uncertain parameters and variables lead to the ineffectiveness of mathematics model, water ecological development strategy, involving diverse factors coming from economic, social and ecological perspective is a typical puzzling problem. So it is of primary interest to apply mathematics model to solve the optimization path in a compact and easy way. In the paper, Intelligent Engineering is applied to describe the state and provide a framework for problem solving while subspace Taboo optimization algorithm is used for optimization seeking in state-space. Finally a case study for water ecology development strategy is given to show the feasibility of the method proposed.

2. Idea of Intelligent Engineering

In this section, we introduce Intelligent Engineering in Intelligent Space [1-3]. The complication of set is both of ordinary set and fuzzy set. State is made of a series of element, which describes difference of the object. Such as $S = (S_1, S_2, \Lambda\ , S_n)$

Where, $S_i (i = 1,2,\Lambda\ n)$ are variable, set and so on.

Definition 1. Intelligent path P is a set of transformations and all the ways between the start state set S0 and destination state set D. It can be in the form as

$$P : S_0 \to D \tag{1}$$

Where S0 is a set of start states, D is a set of destination states.

Definition 2. Let $d \in D$ and $s \in S_0$, P is a set of intelligent path from S0 to D. Then, it is in the form as

$$d = IP(s) \tag{2}$$

Definition 3. Intelligent space is defined as

$$I =< P, S > \tag{3}$$

Where P is the set of intelligent path from S0 to D, S0 and D are subset of S.

Definition 4. A problem B is defined as

$$B =< S_0, D, PB > \tag{4}$$

Where PB is a set of the intelligent path from S0 to D, it is a subset of P in intelligent space I. i.e.

$$PB \subset P \tag{5}$$

Definition 5. A solution ps of the problem B is a element of PB, i.e.

$$ps \in PB \tag{6}$$

Definition 6. A α^- solution for the problem B is defined as SL(a) if there is a fuzzy set fp in PB

$$fp : PB \to [0,1] \tag{7}$$

And

$$SL(a) = \{x \mid \mu_{fp}(x) \geq \alpha, x \in PB\} \tag{8}$$

Where $\alpha \in [0,1]$.

In the case of $x = (P_0, P_1, \Lambda\ P_n)$, then it has to be

$$\mu_{fp}(P_i) \geq \alpha \text{ , for } i = 0,1,2,\Lambda\ n \tag{9}$$

Definition 7. $< PS, St >$ is a subspace of $< P, S >$, iff

$$PS \subset P \tag{10}$$

And

$$St \subset S \tag{11}$$

We can find a series of reasonable path after establishing the intelligent space. There are many kinds of algorithms for finding the reasonable path of intelligent space, such as AI (Artificial Intelligence), NN (Neural Networks) and FS (Fuzzy Systems) etc. However, with different methodologies, the different methods are performing with advantages and limitations respectively. Intelligent space search characterizes problem solving as the process of finding a solution path from a start state S0 to a goal D. i.e. $< PB, St >$ is a subspace of $< P, S >$, we can find the optimization path in set of PB, that is PB^* . Taboo niches algorithm is used for solving these kinds of problem.

3. Taboo Niches Algorithm For States Optimization[4-18]

3.1 Fundamental of Taboo Niches Algorithm

A novel Taboo Niches Optimization approach has been used for finding PB^* in this paper. Here niche is a subspace around a local optimum. The hybrid technique involves dual search stages, namely, random uniform global searching and local niche searching. And then, the searched niche is tabooed. Repeat the above stages until all niches are tabooed one by one. Local searching is only once for each niche. Taboo niches ratio is used as an effective global convergence criterion.

The method in this paper is a hybrid global optimization strategy, which is mainly composed of three parts, global stochastic uniform search, local subspace deterministic search, and local

subspace taboo strategy. The global stochastic uniform search is to distribute the starting points in N^n space for local search by using the uniform stochastic method. The local subspace deterministic search is to implement the local deterministic search in the global stochastic uniform search points, which do not fall into the taboo subspace. The taboo subspace extension means a new local subspace deterministic search that goes into an old taboo subspace and makes the taboo distance increase, so the old subspace is extended.

Definition 8: Niche is the region N^n around a local minimum x_l, when using a descent local search method A from a point x_0 in the region $N^n(x_l)$, the local minimum x_l is only one and can always be located. That is

$$x_l = A(x_0) \tag{12}$$

Where $x_0 \in N^n(x_l)$ and $N^n(x_l) \subseteq PB$. The niche region N^n is a complete set.

From the definition, we can easily get the property of the niches in the feasible space PB. If there are *m* local minima in the feasible space PB, we can easily get the idea that the space PB is composed of *m* different niches. That is

$$PB = \sum_{i=1}^{m} N_i^n \text{ix}_{li} \tag{13}$$

That means the global optimum could be gotten after m local searching at least, and also means the global optimization complexity has a relationship with m.

As the stochastic uniform searching starting point x_0 is in global space PB, any of m niches can be searched by local search method A. But, for avoiding searching an acquired niche repeatedly, a taboo niche list should be setup.

Definition 9: Taboo Niche is an acquired niche that should be forbidden to search again. For this purpose taboo niches list can record the acquired niches.

Definition 10: Hyperspace Niche is a simpler description and approximation of the taboo niche region. If and only if the x_l is the local minimum point and fL the minimum objective function value in a niche, and x_t is a local maximum point, $R_l = \|x_t - x_l\|_p$ is called taboo radius from x_l; the local region, included in a space of R_l as radius and x_l as center, is called as an approximate taboo hypersphere niche N^n.

When norm p =2, the R_l is a Euclidean distance. As the center of the niche is fixed, the hypersphere niches will be overlapped partly each other, but the expression (13) is still tenable.

Definition 11: Let N_a as total points number of global stochastic uniform search, among them, points leading to niches are called starting points N_i; and points falling into the niches are taboo points N_t. They have relationship as

$$N_t = N_a - N_l \tag{14}$$

Definition 12: Let all taboo niches as T^n in feasible space PB, the hypervolume ratio of the two hyperspaces is called taboo niches ratio r_t, which is

$$r_t = \frac{[T^n]}{[PB]} \tag{15}$$

Based on basic theory we know that,

Taboo niches ratio is defined as

$$r_t = \frac{N_t}{N_a} \quad (16)$$

The taboo niches ratio r_t is always a real value in the range [0,1].

Let the number of local optima *m* as a limited value. When $N_a \to \infty$, then $r_t \to 1$.

Let the number of local minimum m as a limited value, and $\forall \varepsilon \in [0,1]$ as lower bound threshold value of taboo niches ratio. When $r_t \geq \varepsilon$, N_a we can always get a finite number.

3.2 Algorithm Description

According to the above fundamental theory, the main steps of the proposed Niche Taboo algorithm are summarized in figure 1.

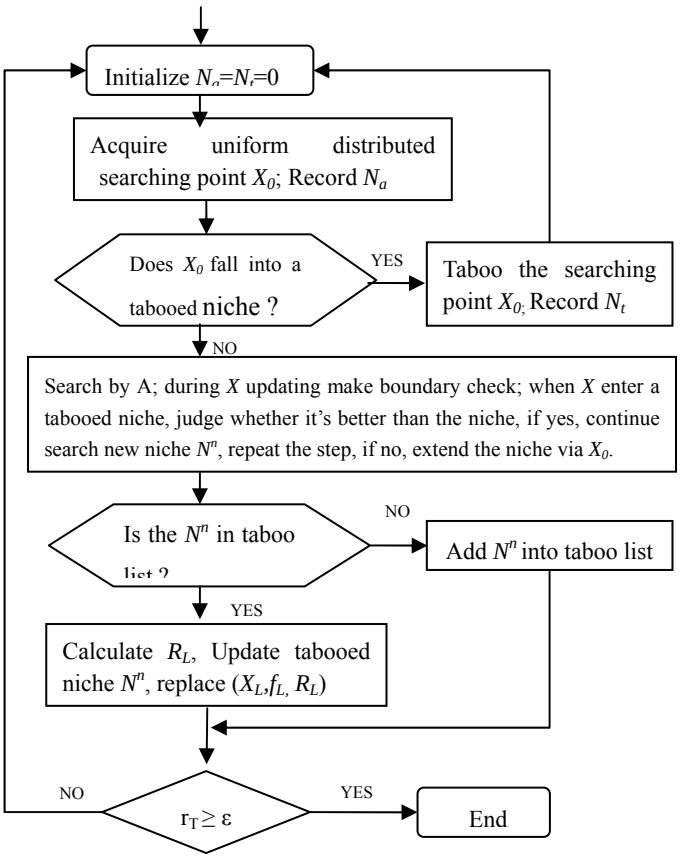

Figure 1 Taboo niches global optimization flowchart

4. Case study---Water Ecological Development Strategy Research

Sustainable development research of water ecology is a key problem in economic society recently. The purpose of water ecological project is to protect the environment and resume the destroyed ecosystem. The development of water ecology study has been restricted by society action, economic factor and ecological index, which is a complex problem that is hard to be described by mathematics model. We can describe the state using intelligent space and then find the optimization path from one state to another by utilizing the above-proposed method.

Let S_0 is the start state of water ecological object in model. It is a ordinal set and can be in the form as $S = (S_1, S_2, \Lambda\ , S_n)$.

Among them element Si belong to different style, such as quantitative, qualitative index and/or society, economic and ecological index etc.

Let $D(t)$ is destination state of water ecological object. Then, it is in form as $D(t) = \left(d_1(t), d_2(t), \Lambda\ d_n(t)\right)$.

These elements in $D(t)$ are corresponding to S_0. Let P is a set of all of path from S_0 to $D(t)$.

Then there is a problem $B = \langle S_0, D(t), PB \rangle$ in the intelligent space. A subspace taboo niches algorithm has been used for solving these kinds of problem.

According to the fundamental concept above, the mail steps of the proposed taboo search strategy are summarized as following:

Step0: To establish the set PB of effective path from intelligent space by IE.

Step1:Initialize Na=Nt=0;

Step2: Do the global stochastic uniform search by using uniform stochastic Monte Carlo method for acquiring the search start point x_0; and record N_a;

Step3: Check up whether x_0 falls into the old Euclidean taboo subspace, if yes, taboo searching x_0 and record the tabooed point number in N_a. Go to step2.

Step4: Do search from x_0 by using the local deterministic optimization algorithm, and find out the taboo subspace. To make boundary check, i.e. record the state of society, economic and ecological factor. When x_0 enters a tabooed niche, judge whether it's better than the niche, if yes, continue search new niche Nn, repeat the step, if no, extend the niche via x_0.

Step5: Check up the taboo search ratio in the solution space. If rt ≥ ε, the global search has achieved convergence, so stop the global search, otherwise, go to step 2.

Step6: According to the optimization path finally, we can determine the laws, rules, institution and strategy for sustainable development of water ecology.

5. Conclusion

In this paper a series of reasonable path can be found based on an intelligent space of Intelligent Engineering (IE). IE is to combine all of the advantages of AI, NN and FS and avoid the limitations of them in solving complex problems. After we find the reasonable path, the method of taboo niches algorithm has been used effectively for solving the optimization path (PB^*) in set of PB. The subspace taboo niches algorithm has the merit of owning lots of global optimum searches, but most of the global exploration is tabooed before taking function evaluations, therefore, the evaluation number is reduced greatly comparing to the similar heuristic taboo search algorithms, and furthermore, making it more universal in applications.

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